The Economics of Railroad Safety

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In Memory of my Grandmother

Madge Lucy Grinyer
1911-1996

CONTENTS

ABBREVIATIONS

AAR	Association of American Railroads
ASLRRA	American Short Line and Regional Railroad Association
CFR	*Code of Federal Regulations*
DOT	United States Department of Transportation
EPA	United States Environmental Protection Agency
FHWA	United States Federal Highway Administration
FRA	United States Federal Railroad Administration
GAO	United States General Accounting Office
ICC	United States Interstate Commerce Commission
NHTSA	United States National Highway Traffic Safety Administration
NTSB	United States National Transportation Safety Board
OHSA	United States Occupational Health and Safety Administration
OTA	United States Office of Technology Assessment
TRB	Transportation Research Board

PREFACE

The American public has a fascination with railroad wrecks that goes back a long way. One hundred years ago, staged railroad accidents were popular events. At the Iowa State fair in 1896, 89,000 people paid $20 each, at current prices, to see two trams, throttles wide open, collide with each other. "Head-on Joe" Connolly made a business out of "cornfield meets" holding seventy-three events in thirty-six years. Picture books of train wrecks do good business presumably because a tram wreck can guarantee a spectacular destruction of property without the messy loss of life associated with aircraft accidents.

A "train wreck" has also entered the popular vocabulary in a most unusual way. When political manoeuvering leads to failure to pass the federal budget, and a shutdown is likely of government services, this is widely called a "train wreck." In business and team sports, bumbling and lack of coordination leading to a spectacular and public failure to perform is also called "causing a train wreck." A person or organization who is disorganized may be labelled a "train wreck."

It is therefore not surprising that the public perception of the safety of railroads centers on images of twisted metal and burning tank cars, and a general feeling that these events occur quite often. After a series of railroad accidents, such as occurred in the winter of 1996 or the summer of 1997, there are inevitable calls that government "should do something."

However, the reality of railroad safety is much different from the perception. The major safety issues are not collisions or derailments, but rather occupational injuries to employees, collisions with negligent road users at highway grade crossings, and the general proclivity of people to trespass on the railroad. Contrary to popular perception, accident rates have fallen throughout the twentieth century. Employee injury rates are a third of those of a generation ago, and grade crossing fatalities per automobile owned have fallen by half over the same period. It is ten times safer to travel by train than to drive.

Yet the railroads are subject to considerable safety regulation. It may come as somewhat of a shock to many readers to realize that much of this regulation is quite recent. Back in those halcyon days when passenger trains were the primary means of long-distance travel, the industry had little formal governmental regulation but substantial self regulation. Then in 1970 the ***Federal Railroad Safety Act*** gave government rulemaking authority over "all areas of railroad safety." Nowadays the ***Code of Federal Regulations*** reads like an engineering textbook on how to build, maintain and operate a railroad.

A generation ago, transportation economists were at the forefront of questioning whether economic regulation of ***prices*** and ***quantity*** of service by government was in the public interest. This book explores whether similar questions can be raised about regulation of the ***quality*** of service: What is the justification for the current safety regulations of the railroads? Why did it happen? Are the current regulations in the public interest? Are there better alternatives?

ACKNOWLEDGMENTS

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1 SETTING THE SCENE

THE BIG PICTURE

To the lay person the image of railroad safety is of spectacular tram wrecks and burning tank cars. However, the reality is much different. Just over 1,000 people were killed on the railroad in 1996 (table 1.1). Deaths due to grade-crossing accidents and trespassing account for ninety-two percent of all fatalities. In 1996 these two causes of death were of roughly equal magnitude. Preliminary figures for 1997 suggest that trespassing fatalities will exceed those at grade crossings for the first time in over half a century. Compared with these risks, highly-visible collisions and derailments accounted for the deaths of nine passengers and eleven employees.

Table 1.1: Fatalities and Injuries by Type of Person 1996

	Fatalities	Iniuries
Employees and contractors	42 (4.0%)	9635 (76.7 %)
Highway users at grade crossings	487 (46.9 %)	1505 (12.0%)
Trespassers not at grade crossings	471 (45.3 %)	474 (3.8%)
Non-trespassers (public lawfully on the railroad / adjacent to the railroad)	27 (2.6%)	431 (3.4%)
Passengers on trains	12 (1.2%)	513 (4.1%)
TOTAL	1039	12558

Source ***for all*** **tables** ***in chapter 1:*** **FRA (1997a,b)**

EMPLOYEE FATALITIES & INJURIES

Railroad work is hardly a risk-free occupation. Much of the work has to be undertaken outdoors in the elements, sometimes in hostile terrain far from medical care, and using heavy moving machinery. Fatality and injury rates vary by the type of work undertaken (table 1.2). Locomotive and train crews, and way and structure maintenance personnel face the highest annual risk of fatal injuries of 1 in 4,200 and

Table 1.2: Casualties per 100,000 Employees for Class I Railroads 1996

	Fatalities	Injuries
Train and Locomotive Crew	23.6	3,914
Maintenance of Way and Structure	20.2	3,320
Maintenance of Equipment and Stores	2.8	3,348
Executives, Officials, Staff Assistants, Professional and Administrative Staff	3.0	813
Operations Employees (not train & loco)	0.0	3,967

The data represent the large ("Class I") freight railroads which account for 80% of industry employment (AAR, 1997). Data are not available on the numbers of employees by job type for smaller railroads.

Table 1.3: Leading Employee Fatality and Injury Risks 1996

Employee Type	Hazard Type	Risk per 100,000 Employees
FATALITY RISKS		
Train Crew	Collisions & Derailments	14.0
Way & Structure	Maintenance work (train moving)	10.3
Way & Structure	Maintenance work (no train moving)	6.1
Train Crew	Coupling & Uncoupling	2.5
Train Crew	Falls	2.5
INJURY RISKS		
Way & Structure	Maintenance (no train moving)	3,800
Equipment & Stores	Maintenance (no train moving)	3,500
Train Crew	General operations (no train moving)	1,650
Train Crew	Falls (no train moving)	1,100

Casualty figures by job category and circumstance of injury are given for the entire industry. To obtain a denominator of risk, employment in the large freight railroads in each job category is inflated by 1.23 which is the ratio of total railroad employee-hoursto employee-hoursin Class I freight railroads (FRA, 1997a). As a result of this approximation, this table may not be directly comparable with table 1.2.

1 in 5,000 respectively. Workshop employees, managerial and clerical staff, and those operations personnel not involved in actually staffing the trains rarely suffer fatal injuries. The injury rates of all non-managerial and clerical staff are remarkably uniform at an annual risk of injury of between 1 in 25 and 1 in 30.

The leading causes of employee fatalities and injuries are shown in table 1.3. The table shows the type of employee exposed to the risk and the annual risk per 100,000 employees of that type. The most severe fatality risks are those posed by collisions and derailments to train and locomotive crew, and in maintenance work for track workers. Deaths by these causes represent two-thirds of all employee fatalities. Train crews are also exposed to fatality risks during coupling and uncoupling operations, and from falling while getting on or off rolling stock or while walking beside the track.

In stark contrast to the fatality risks, eighty-five percent of employee injuries do not involve a moving train. The leading risks are to workers who are maintaining equipment or way and structure. The next highest risks are faced by train and locomotive crews coupling and uncoupling stationary locomotives or cars, operating switches, falling from stationary rolling stock, or slipping while walking.

HIGHWAY GRADE CROSSINGS

There are 265,000 rail-highway grade crossings in the United States. This large number is partly a consequence of geography, and partly a legacy of history. In the plains of the Midwest and South most highway crossings are at-grade rather than on bridges or in underpasses. In the early days of railroading a crossing was provided at every point where a road intersected the right of way to accommodate horse and buggy traffic. There has been a reluctance to close crossings, despite the fact that many see little road traffic and have alternative crossings close by.

Sixty percent of crossings are by public highways. The other forty percent are ***private crossings*** which are used solely by agricultural (24 percent), industrial (9 percent) or residential (5 percent) users whose property is adjacent to the railroad (table 1.4). About two-fifths of the public crossings are equipped with ***active warning devices*** such as flashing lights, bells, gates, highway stop lights or manual flagging of trains that indicate to road users that a train is approaching. Most of the remaining public crossings have ***passive warning devices*,** such as "crossbucks" or stop signs, that warn the road user of the existence of the crossing but do not show any indication of whether a train is approaching.

Of course, active warning devices are primarily installed at the busiest crossings. Eighty-four percent of crossings with an average daily road traffic of greater than 5,000 vehicles have active warning devices. Currently about 500 crossings are upgraded from passive to active warning devices each year. Very few private crossings have active warning devices. Indeed threequarters of them do not even have warning signs.

Table 1.4: Numbers of Crossings by Type 1996

	Type of Crossing Warning			
	Active	Passive	None	Total
Public Crossings	65,667	90,709	6,050	162,426
Private Crossings	1,069	24,959	77,267	103.295
				265,721

During 1996, 415 motor-vehicle users, 71 pedestrians and one railroad employee were killed at grade crossings. Only 39 fatalities, or nine percent of the total, **occurred** at private crossings despite the fact that these crossings represent forty percent of all crossings. Because data on road traffic usage of private crossings are not collected, one cannot be certain whether there is a higher or lower risk at private crossings compared with public crossings.

Information is available on motor-vehicle, but not pedestrian, fatalities at public crossings by the type of warning devices installed (table **1.5),** and on the distribution of road traffic at public crossings with different types of warning devices. Therefore one can estimate fatality rates per billion road-vehicle crossings. As shown in table 1.6, crossings that are only provided with passive devices have a fatality risk four times that of crossings with active warning devices. There were no fatalities at public crossings without warning devices in 1996. The good record of the latter type of crossing is probably because sixty-eight percent of these crossings witness two trains a day or less.

Sixty percent of collisions occur in rural areas (National Highway Traffic Safety Administration (NHTSA), 1994). While road traffic may be heavier on urban crossings, these crossings are likely to be provided with active warning devices. The location of collisions is quite dispersed and not concentrated on a few ***black-spot*** crossings. Over the seven-year period from 1988 to 1994, collisions occurred at fourteen percent of crossings. Most crossings only experienced one collision, but three-and-one-half percent experienced two or more.

Grade-crossing collisions have characteristics that are both similar and different from highway crashes in general. A disproportionate number of highway crashes occur in the late evening. In contrast, grade-crossing collisions occur at all times of day. Indeed sixty percent of collisions occur in daylight hours. There is a higher involvement of older drivers in grade-crossing collisions than in highway crashes in general, and a lower involvement by younger drivers. That said, drivers

Table 1.5: Motor Vehicle Fatalities by Crossing Type 1996

	Type of Crossing Warning			
	Active	Passive	None	Total
Public Crossings	168	***209***	***0***	***377***
Private Crossings	0	31	***7***	***38***
				415

Table 1.6: Author's Estimate of Motor Vehicle Fatality Risk per Billion Vehicle Crossings at Public Crossings 1996

At crossings with active warning devices	1.74
At crossings with passive warning devices	***7.45***
At crossings with no warning devices	0.00

under the age of thirty-five still account for fifty-six percent of grade-crossing fatalities. As with highway crashes in general, four-fifths of grade-crossing fatalities are male. A third had been drinking, and a quarter had a blood-alcohol content greater than the legal limit.

The proportion of crossing collisions that are due to road user negligence or inattention is unclear. Road user negligence may play a small role in the quarter of total collisions where a stationary motor vehicle is struck by a train. These collisions fortunately result in only nine percent of total crossing fatalities presumably because people have time to exit the motor vehicle. More questionable levels of road-user negligence are involved in the half of **all** collisions where a vehicle moving across the crossing is struck by a tram. Considerable road user negligence is likely in the quarter of all collisions where the road user enters the crossing so late as to drive into the side of the tram. Indeed in ten percent of collisions the road user strikes the train behind the leading rail locomotive or car! At gated crossings, eighty-six percent of the fatalities occur when the road vehicle drives around or through the closed gates. At crossings with flashing lights, **ninety-**two percent of the fatalities occur when the road user ignores the light signals.

TRESPASSERS

Throughout this book "trespassers" will be defined as those people trespassing at locations other than grade crossings. Almost 500 trespassers are killed each year. This total does not include fatalities that are judged suicides by a coroner. Undoubtedly some of the recorded trespasser fatalities are by suicidal people who do not leave notes or other evidence of their intentions. As shown in table 1.7, a third of the trespassers were killed while sitting or lying in the right of way which may suggest deliberate endangerment by the victim. A study in Britain, where reporting requirements are similar to the United States, looked at circumstantial evidence and found that up to half of all reported trespasser fatalities were probably by people with suicidal intent (Railtrack, 1994).

Two studies give some insights into whom trespassers are, and the circumstances and locations in which they are struck by trains. **One** is a National Transportation Safety Board **(NTSB,** 1978a) study of 280 fatalities that occurred between March 1976 and October 1977. The other examined coroners' reports for all of the 138 trespasser deaths in North Carolina for the years 1990-94 (Pelletier, 1997). The results of the two studies are almost identical.

More than ninety percent of victims are adult males, with the vast majority between the ages of 20 and 49. Eighty percent of the adult victims are unmarried. Pelletier's study found that for those adults whose education was known, only **forty-**five percent had graduated from high school. Only about ten percent were transients. Eighty percent of deaths occurred within the victim's county of residence which suggests that trespassers are killed close to home. Pelletier found that blacks were overrepresented as thirty-eight percent of the victims whereas they formed only twenty-two percent of the population of North Carolina.

Table 1.7: Trespasser and Non-Trespasser Fatalities by Cause

	1996 Trespassers	1992-5 Non-trespassers
Struck by train while . .		
walking on the track	216 (46%)	29 (27%)
sitting or lying on the track	167 (35%)	25 (24%)
crossing the track	28 (6%)	7 (7%)
crossing a bridge or trestle	14 (3%)	2 (2%)
passing under or over a car	5 (1%)	1 (1%)
Collisions and derailments	12 (3%)	4 (4%)
Falling, hit by flying objects, bums	9 (2%)	4 (4%)
Getting on / off rolling stock	8 (2%)	
Other	12 (3%)	34 (32%)
	471	106

The data on non-trespassers were obtained from the original FRA database so as to exclude fatalities by contractor's employees.

In contrast to the grade-crossing problem, the trespasser problem appears to be an urban one with less than a quarter of fatalities occurring outside of city or town limits. The NTSB reports that nearly all of the fatalities occurred on multiple-track mainlines. In eighty percent of the cases there was no fence erected to protect the right of way.

A disproportionate number of fatalities occur at night on the weekends. Sixty percent of the victims in the NTSB study and eighty percent in Pelletier's study had been drinking heavily. The average blood-alcohol content was 0.23 which is two to three times the legal limit for driving, and according to the National Safety Council puts a person in a state of "confusion." Twenty-eight percent of victims in Pelletier's study had previously received medical treatment for alcoholism.

NON-TRESPASSERS

This rather clumsy term covers a multitude of different people. The official definition is "a person who is lawfully on any part of railroad property which is used in railroad operations or a person who is adjacent to railroad premises when injured as a result of railroad operations." Examples of non-trespassers include: utility crews working on or near the railroad; shippers' representatives at sidings; truck drivers delivering freight to yards; official guests of the railroad; passengers when they are not on a train or boarding and alighting from one; and third parties adjacent to the railroad who are injured by a railroad accident. In some tables in the official statistics, fatalities to employees of contractors are included in this definition, but I have included these people with employees.

There were 106 non-trespasser fatalities over the four-year period 1992-95. A special analysis was conducted using the federal accident database to determine the circumstances of these fatalities (table 1.7). Three people were bystanders who were killed by train accidents: one person was struck by a runaway freight car; another was a highway user who was hit by a derailed freight car falling off a bridge; and the third occurred when shrapnel from a railroad accident landed on a highway. Only one person is recorded as having been "working on or along the track." Fourteen people could well have been passengers at stations who were killed by an assault, flying objects, **falling,** or crossing the tracks.

However, the circumstances of eighty percent of non-trespasser deaths do not seem to be consistent with the official definition: 25 victims were sitting or lying in the right of way, 29 were walking along the tracks, and 31 deaths were undefined as to cause. Moreover, a third of all non-trespasser fatalities are people under the age of fifteen. It is possible that very young victims may be misclassified by those completing the accident-report forms as non-trespassers due to confusion as to the legal definition of whether persons under the age of twelve can be held legally responsible for knowing that they are trespassing. I have a strong suspicion that many of the recorded non-trespasser victims are in fact trespassers whose purpose on the railroad was mistakenly reported on accident-report forms.

PASSENGERS ON TRAINS

Twelve passengers were killed in 1996 and about 500 injured (table 1.8). Total fatalities were somewhat above the typical annual average due to the collision and train fire at Silver Spring, Maryland. Absent a major disaster, there are usually three to five passenger deaths a year, most due to boarding and alighting accidents. Boarding and alighting also causes about a third of total passenger injuries, with another quarter due to passengers falling while moving about within the train.

Table 1.8: Passenger Casualties by Cause 1996

	Fatalities	Iniuries
Boarding and alighting	2 (17%)	156 (30%)
Fallings, flying objects, burns	**1 (8%)**	132 (26%)
Collisions and derailments	9 (75%)	**111 (22%)**
Operation of doors and windows		**41 (** 8%)
Result of grade-crossing accident		24 (5%)
Other causes		49 (10%)
	12	513

COLLISIONS AND DERAILMENTS

In 1996 there were 205 collisions and 1816 derailments which were serious enough to cause either a fatality, an injury, or more than $6,300 of damage to railroad property. These accidents resulted in the deaths of nine passengers, eleven employees and twelve trespassers. In addition, 111 passengers and 127 employees sustained injuries. While the number of fatalities and injuries is quite small, collisions and derailments result in substantial amounts of damage to railroad property, shippers' goods, and the property of people adjacent to the railroad. In recent years there has been increasing concern about accidents that result in a release of hazardous materials. During 1996, thirty-four separate accidents caused the release of hazardous materials from sixty-nine cars, and resulted in the evacuation of 8,547 people from their homes or workplaces.

Table 1.9: Collision & Derailment Accidents by Location 1996

	Collisions	Derailments
Main line	53 (26%)	752 (41%)
Yard Track	135 (66%)	858 (47%)
Siding	17 (8%)	206 (11%)
	205	1816

As can be seen in tables 1.9 and 1.10, the majority of both collisions and derailments occur in yards or sidings during switching operations, with collisions due to poor operating procedures, and derailments due to poor track. On the main line the major causes of collisions are inappropriate brake use and failures in dispatching and signaling. For derailments the most prevalent cause is track condition, primarily geometry defects and broken rails, with a substantial number caused by defects with car trucks, axles or journal bearings.

About a third of collisions and derailments are due to incorrect operating practices. The NTSB (1972) investigated these instances of employee negligence using data from the 1960s. Using an index that combined frequency of occurrence and severity of outcomes, the NTSB concluded that ten leading operating-practice failures were (in descending order): disregard of a stop signal, excessive speed on the main line, improper switch setting, disregarding a restricting signal, failure to secure handbrakes, absence of a lookout on the leading car of a propelled tram, excessive speed in yards, failure to provide flag protection, moving locomotives without orders, and failure to clear a train beyond the fouling point at switches.

Table 1.10: Causes of Collision & Derailment Accidents 1996

	Collisions		Derailments	
Track, roadbed and structures		4%		48%
Locomotive failure		0%		1%
car failure		6%		13%
Operating practices				
Incorrect braking	10%		2%	
Drugs, alcohol, fatigue	1%		0%	
Signaling	17%		1%	
switching	38%		11%	
Train handling	4%		7%	
Speed	4%		1%	
Other	4%	78%	1%	23%
Other (mainly environmental)		12%		15%

2 HISTORICAL TRENDS

The previous chapter described contemporary safety. The next two chapters set the current performance in its historical context. This chapter describes trends in safety since statistics were first collected in 1890. The next chapter describes how public policy toward safety has responded to, and influenced, these trends.

SOURCES OF DATA

The Interstate Commerce Commission (ICC) started to collect information on collisions and derailments in 1901. In 1910, the ***Accident Reports Act*** required that railroads report all accidents to the ICC. Summary data are made available to the public in an annual publication entitled ***the Accident / Incident Bulletin.*** Data analysis and publication of this report subsequently passed to the Federal Railroad Administration **(FRA),** a division of the federal Department of Transportation (DOT). In the early years the ICC retroactively collected data from as far back as 1890. This chapter looks at safety trends since 1890. It primarily focuses on fatalities and injuries rather than the number of accidents. This is because the definition of an "accident" has changed over time. The most serious problem is with the threshold dollar figure, currently $6,300, used to determine whether a property-damage-only accident is reportable. This threshold has not changed consistently with inflation over the years. Most notably, the dollar threshold remained constant during the late 1960s and early **1970s,** a period of both rampant inflation and public debate about supposedly worsening safety.

AGGREGATE CASUALTIES

Figures 2.1 and 2.2 present aggregate numbers of fatalities and injuries at the turn of each decade since 1890, and the average for 1994-96. The base data are given in appendix tables **B1** and B2. Figure 2.2 does not include injury data for employees because of a definitional change in 1975. Prior to 1975, "injuries" were only counted if they required the employee to miss more than two workdays. This changed to a much more encompassing **definition** which lead to a threefold increase in reported injuries.

The number of fatalities and non-employee injuries increased to reach a peak in 1910. The next two decades saw a sharp drop, and the improvement continued

Figure 2.1: Annual Railroad Fatalities

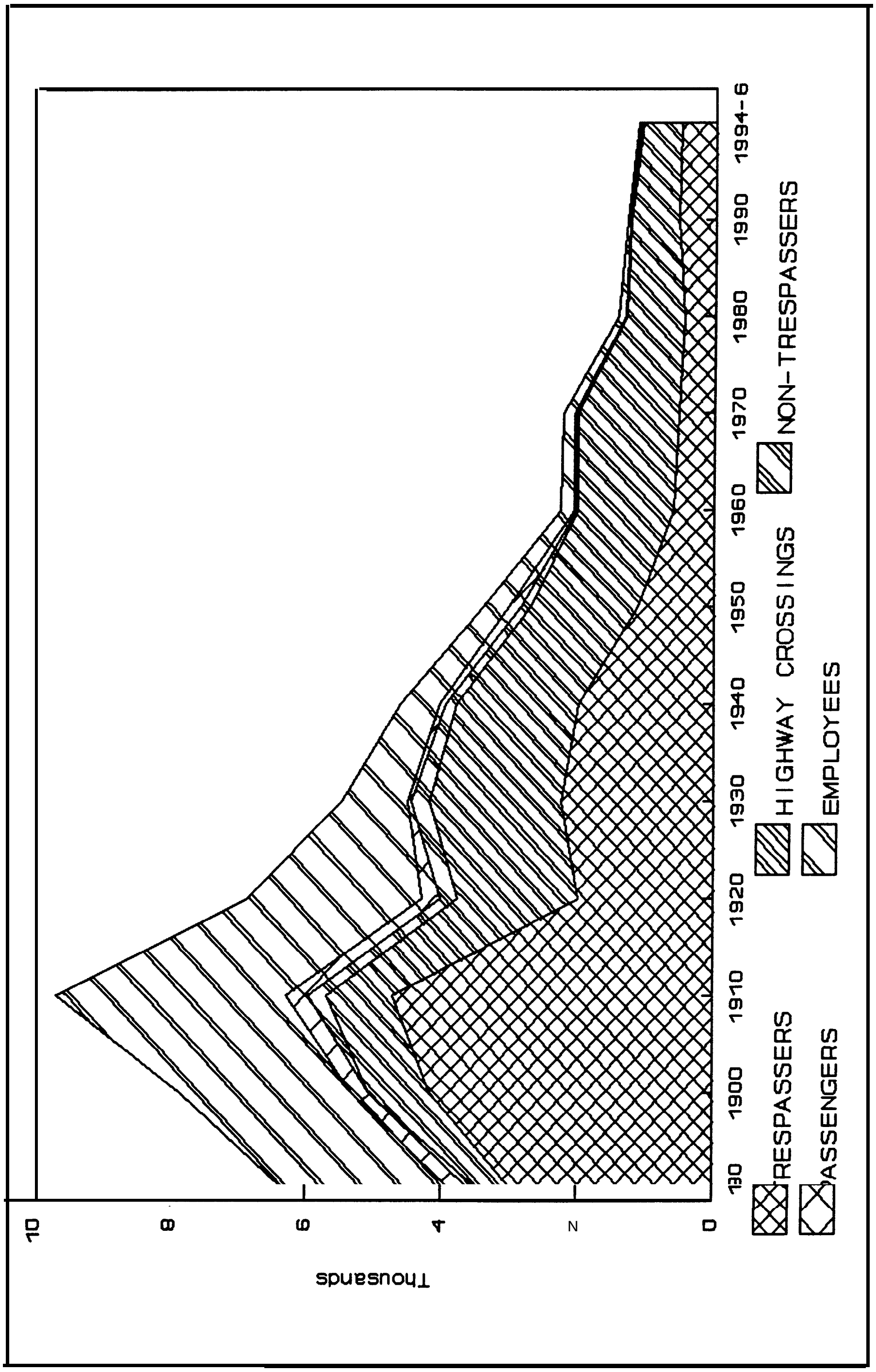
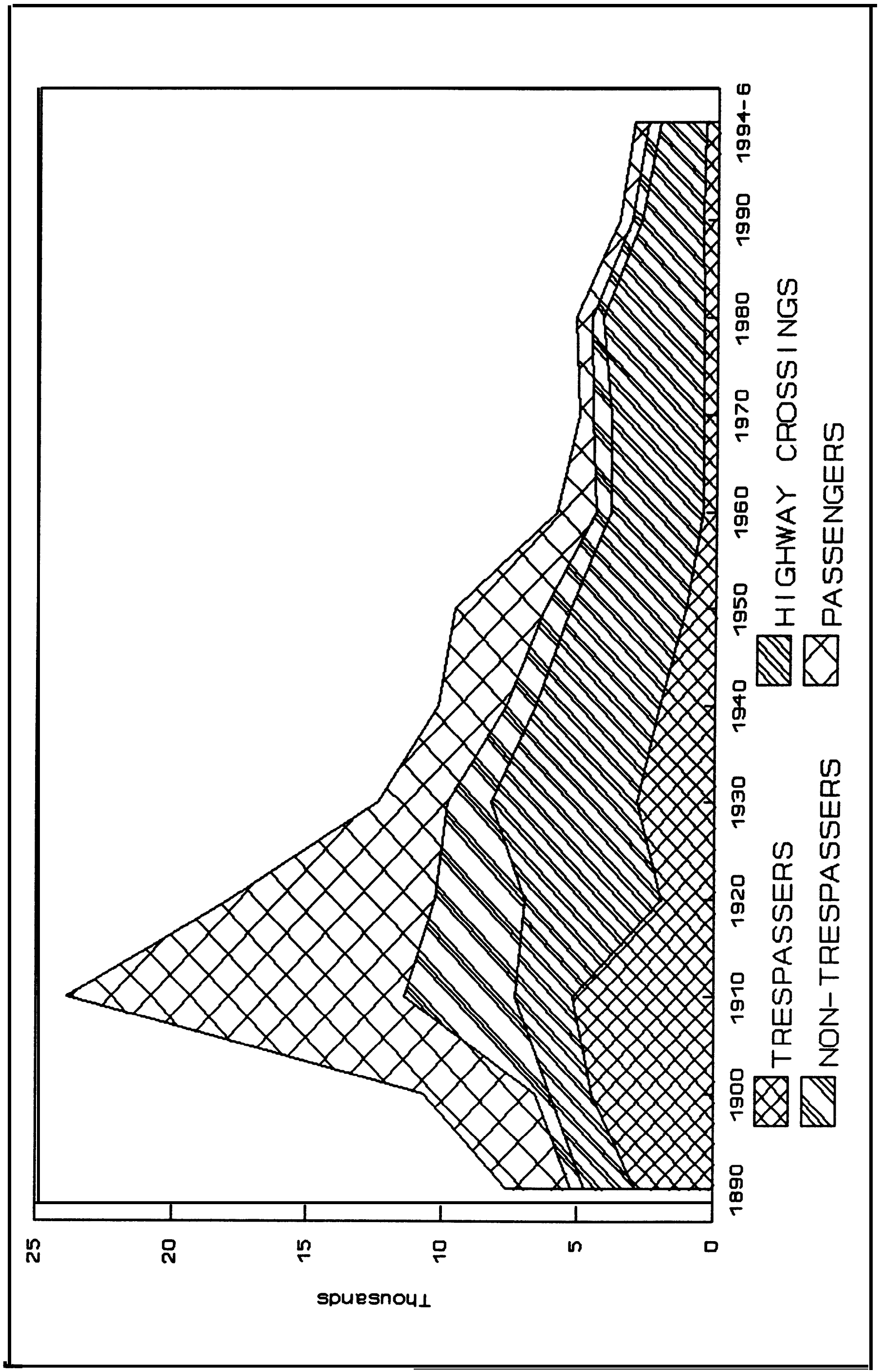


Figure 2.2: Annual **Railroad** Injuries (Excluding Employees)



until 1960. There was then a leveling off of performance until fatalities started to decline again in the 1970s, and injuries started to decline in the 1980s. Today the annual number of railroad fatalities is only half of what it was in 1960, and an eighth of the number in the peak year of 1910.

Of course, the absolute numbers present only part of the picture. Exposure to accidents has also changed. Passenger miles have declined, employee numbers have fallen drastically, and highway traffic has increased. Data for some important exposure measures are given in table B3 in appendix B. The next sections of this chapter combine exposure measures with the fatality and injury data to produce casualty rates for employees, highway-crossing users, trespassers, and passengers.

EMPLOYEE CASUALTY RATES

Casualty rates per billion employee hours are shown in table 2.1. Immediately noticeable is the leap in injuries after 1975 caused by the definitional change that was referred to above. There are three major periods of interest. The first is during the 1920s when there was a forty percent reduction in fatality rates and a two-thirds reduction in injury rates. The second is the 1960s when the steady improvement in casualty rates was reversed. The third period is since 1980 when injury rates have fallen by two-thirds, and fatality rates by one-third.

Table 2.1: Employee Casualty Rates per Billion Employee Hours

Year	Fatalities	Injuries	Year	Fatalities	Injuries
1920	395	26790	1980	96	55718*
1930	249	9397	1990	72	37879*
1940	210	7054	1994	60	25220*
1950	132	7995	1995	67	21131*
1960	112	7560	1996	65	18230*
1970	130	13174	* definitional change in 1975		

Excluding casualties to employees not-on-duty and contractors. Data on employee hours were first collected in 1916.

HIGHWAY-CROSSING USER CASUALTY RATES

Highway grade-crossing user casualty rates since the mass introduction of the motor vehicle in 1920 are shown in table 2.2. Relative to the number of train miles, casualty rates peaked in 1970, and have subsequently fallen substantially and are now under half of what they were in 1970. Given the massive expansion in automobile ownership, perhaps a more relevant measure of the changes in risk over time is the rate of casualties per million highway vehicles. The improvement in

Table 2.2: Highway-Crossing User Casualty Rates

	Per Billion Train Miles		Per Million Vehicles	
	Fatalities	Injuries	Fatalities	Injuries
1920	968	2327	193.1	[illegible]
1930	1221	3365	72.6	200.1
1940	1374	3477	56.2	142.2
1950	1128	3056	31.8	86.1
1960	1417	3360	19.1	45.3
1970	1769	4010	13.7	31.0
1980	1159	5182	5.3	23.9
1990	1138	3651	3.7	11.8
1994	937	2671	3.1	8.8
1995	860	2518	2.9	8.4
1996	726	2243	2.4	7.5

safety is much more pronounced using this measure, and has improved continually since the introduction of the automobile. Casualty rates per road vehicle are about a sixth of those in 1970 and a thirteenth of what they were in 1950.

TRESPASSER CASUALTY RATES

Trespasser fatality and injury rates are shown in table 2.3. Relative to the number of train miles the trend is somewhat mixed. There was a large decline between 1900 and 1920, and then a more gradual downward trend until 1960. Since then there has been a worrying upward trend. Fatality and injury rates per train mile are now twenty percent higher than in 1960. However, the population of the United States has grown threefold since 1910 and by almost half since 1960. Relative to the population of the country, casualty rates have fallen continuous since the start of the century, although there does appear to be some leveling off since 1980.

The leveling off of casualty rates since 1980 coupled with a fifteen percent increase in the population accounts for the increasing number of trespasser fatalities in recent years. Unless casualty rates fall, the absolute number of trespassers killed and injured each year will continue to climb as the population expands. Preliminary data for 1997 suggest that the number of annual trespasser fatalities will exceed the number of fatalities at grade crossings for the first time since 1941. Yet as recently as 1970 the number of grade-crossing fatalities exceeded those of trespassers by a ratio of 2.8:1.

It is quite astonishing to realize that trespasser fatalities per head of population were ten times higher than current levels in the 1920s and 1930s. In part this is explained by the large number of hoboes who rode the trains during the depression years. It is also true that more people were exposed to trespassing risks earlier this

Table 2.3: Trespasser Casualty Rates

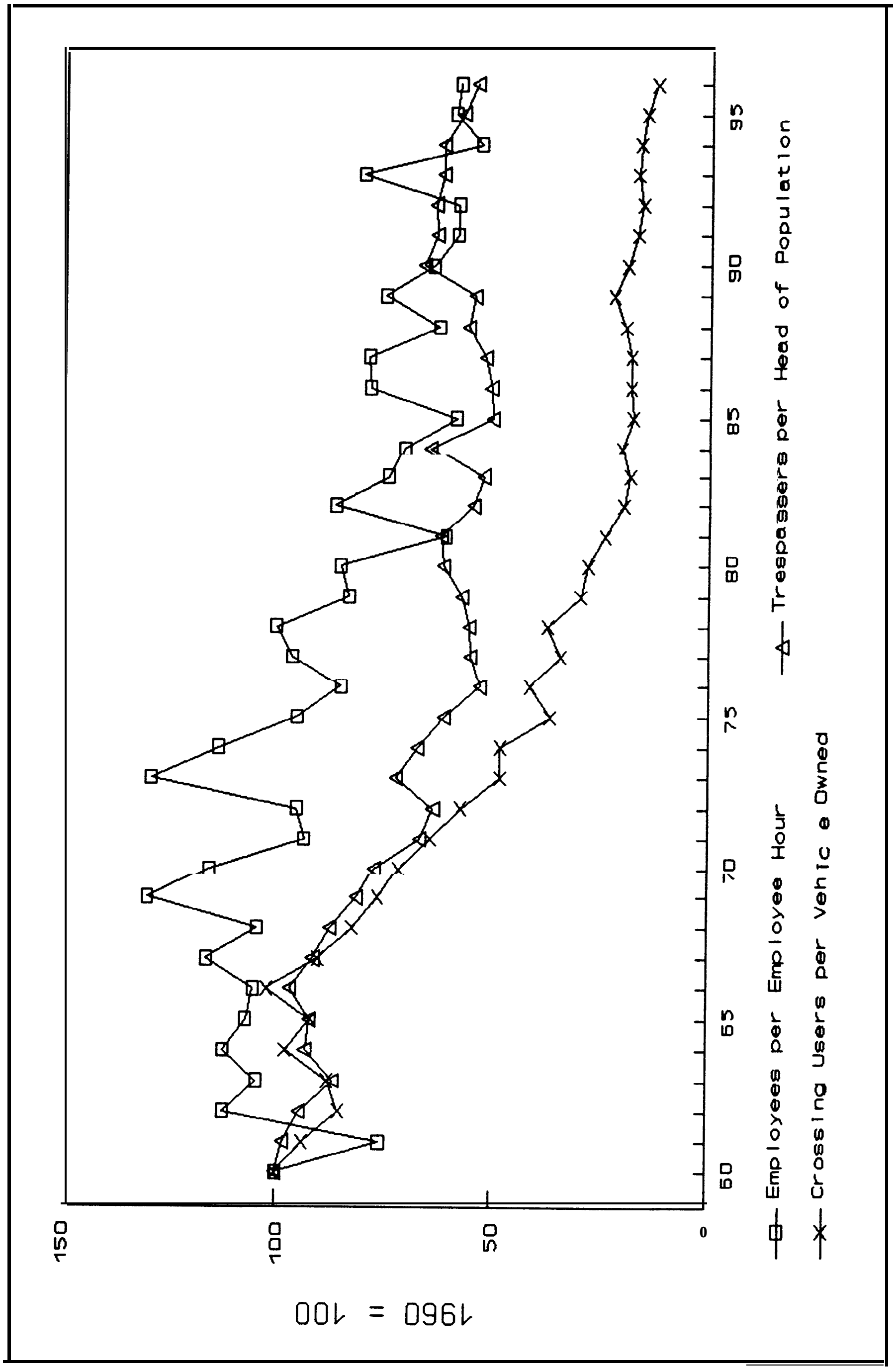
	Per Billion Train Miles		Per Million U.S. Residents	
	Fatalities	Injuries	Fatalities	Injuries
1890	4111	4010	47.09	45.93
1900	4708	5047	54.94	58.90
1910	3875	4251	51.48	56.49
1920	1073	1036	18.71	18.06
1930	1407	1790	18.23	23.20
1940	1519	1533	15.10	15.24
1950	809	759	7.38	6.93
1960	589	505	3.24	2.78
1970	616	607	2.52	2.48
1980	637	637	2.01	2.08
1990	892	920	2.17	2.24
1994	808	690	2.03	1.73
1995	737	696	1.88	1.77
1996	702	707	1.77	1.79

century because the railroads served a mass market, and provided extensive freight and passenger service to small communities. Expressed as a rate per train mile, trespasser fatality rates were twice current levels in the 1920s and 1930s. It is also quite clear that in the early days of railroading the public was quite complacent about trespassing risks. The casualty rate per head of population was thirty times higher in 1900 than it is today, and the rate per train mile was six times higher.

SUMMARY OF RECENT TRENDS

To summarize recent trends, figure 2.3 shows fatality rates for employees, trespassers and grade crossing users each year since 1960. Employee fatalities are expressed relative to employee hours, trespassers relative to the United States population, and crossing fatalities relative to the number of motor vehicles registered. All of the fatality rates are shown as an index with 1960 set equal to 100. Fatality rates at crossings have recorded the most impressive improvement falling rapidly since 1967. The trespasser fatality rates also started to decline rapidly after 1967 but leveled out after 1975 at about forty percent below the fatality rate in 1960. If anything, there may be a slight upward trend in recent years. Employee fatality rates show a different pattern with an upward trend in the 1960s and early **1970s,** and a subsequent improvement. In the peak years of the early **1970s,** fatality rates were thirty percent above those in 1960, and twice what they are now.

Figure 2.3: Railroad Fatality Rates since 1960



PASSENGER CASUALTY RATES

Passenger fatality and injury rates per billion passenger miles are shown in table 2.4. For the period when passenger traffic was extensive, and accidents frequent, the data are shown at the turn of each decade between 1890 and 1940. For the postwar years, when the decline in passenger traffic has meant that major disasters with much loss of life occur rarely and randomly, average casualty rates are calculated for three periods: 1946-1959, 1960-1979, and 1980-1996. In recent years, passenger fatality rates are only half of what they were in the immediate postwar years, and a thirteenth of those when railroads were the primary means of travel at the beginning of the twentieth century.

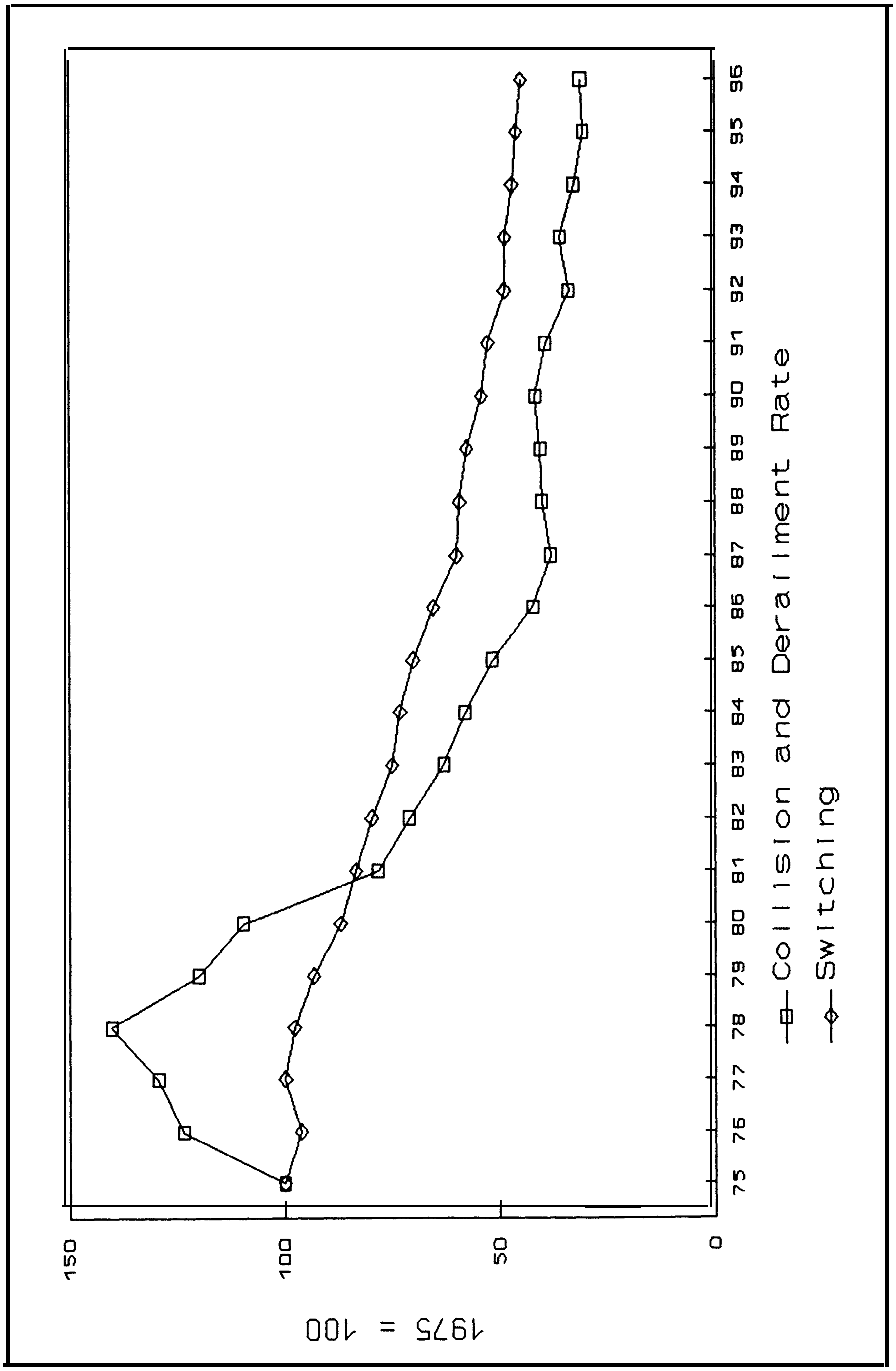
Table 2.4: Passenger Casualty Rates per Billion Passenger Miles

Year	Fatalities	Injuries	Year	Fatalities	Injuries
1890	24.14	205	1940	3.65	105
1900	15.52	257	1946-59	1.64	78
1910	10.02	385	1960-79	1.07	82
1920	5.57	160	1980-96	0.73	42
1930	2.01	95			

COLLISIONS AND DERAILMENTS

Data on collisions and derailments can only be meaningfully analyzed since 1975 when the dollar threshold for reporting property-damage-only accidents started to be adjusted for price inflation. The rate of collisions and derailments per train mile is shown in figure 2.4 as the line with the squares. It is shown as an index with the value in 1975 set equal to 100. The rate increased until 1979 and subsequently declined. It is now only a quarter of what it was in the late 1970s. One explanation for this reduction is a change in the way that railroads do business. Railroad mergers and the move toward unit trains and away from single-car service have reduced the amount of switching. In the mid 1970s switching represented about thirty percent of all train miles while that ratio is now thirteen percent. The line with the diamonds represents this ratio with the value in 1975 set equal to 100. As seventy percent of collisions and sixty percent of derailments occur in yards and sidings, it is not surprising that the rate of collisions and derailments has fallen. Albeit that the decline in the rate of collisions and derailments since 1979 has been much swifter than the decline in switching operations which suggests that there must be other factors at work.

Figure 2.4: Collision and Derailment Rate since 1975



3 PUBLIC POLICY

This chapter provides a sketch of the development of public policy towards railroad safety. There are four key dates in this history: 1853, 1893, 1900-1910 and 1970. Readers seeking more details are directed to Robert Shaw's 1978 book A ***History of Railroad Accidents, Safety Precautions and Operating Practices*** which provides an encyclopedic review of the period prior to 1950. Another source is Robert Reed's 1968 book ***Train Wrecks: A Pictorial History of Accidents on the Main Line.*** While primarily a picture book, it does provide a quick, readable and informative introduction to the subject.

1853: THE YEAR OF DISASTER

In the 1830s and 1840s there was little public concern about safety. The network was small, speeds were low, traffic was light and there was little nighttime operation. No wreck claimed more than six lives. That changed in 1853. A series of wrecks claiming 234 lives, injured the president-elect, and led to considerable public outrage. An editorial in the ***Railroad Record*** opined:

> "Public feeling has been grossly outraged by these reckless sacrifices of life on railroads. Indignation meetings have been called, and several Legislatures have taken action upon the matter. We sincerely trust they will continue to agitate the matter until some remedy shall be applied to this great evil. Corporations have no souls, but they have pockets, and if they cannot be reached in any other way, heavy damages should be required of them in every instance where loss of life was the result of carelessness."

and a New York paper editorialized:

> "That a vast majority of railroad disasters are directly owing to stupidity and neglect of the employees, and the apathy and avarice of the railroad officers."

The carnage continued into 1854, 1855 and 1856 and remained a serious problem through the Civil War. The situation was inflamed by sensationalist press reporting which would make today's coverage of aviation accidents look gentile. Screaming headlines and very graphic lithographs and text made such accidents as Camp Hill, Pennsylvania **(1856),** the "Angola (New York) Horror" **(1867),** Ashtabula, Ohio (1876) and Chatsworth, Illinois (1887) part of popular folklore. Despite the publicity, Shaw (1978) notes that the railroads were much safer than the stagecoaches they replaced, and considerably safer than contemporary steamboats which routinely exploded and sank.

The root cause of the safety problem was the hasty construction of new lines by undercapitalized firms who wished to take advantage of land grants. This resulted in sharp curves, poorly-constructed wooden bridges, steep grades, light rolling stock, and inadequate road bed which could not cope with frosty and muddy conditions. Often minor derailments and collisions were made worse by the telescoping of flimsily constructed wooden carriages and the threat of fire from coal-heating stoves and kerosine lighting. Rear-end and head-on collisions were a persistent problem. Prior to the invention of the telegraph in 1855, trains were dispatched **from** stations based on the published timetable. This method of protection was useless when trains were delayed or stalled between stations; Even when it came available, not all companies invested in telegraph, so head-on collisions persisted into the 1880s.

1893: THE FIRST REGULATION

Despite the outrage in the **1850s,** it was to be thirty years before there was any major political intervention. In the 1880s the state legislatures in Ohio, Illinois, New York and Massachusetts started to conducted investigations of major accidents. A proposal was introduced into the New York legislature to set up a State Railroad Commission to deal with safety issues. This was blocked by State Senator Webster Wagner, a car builder and railroad ally. Ironically he perished in the rear-end collision at Spuyten Duyvil in 1882 and the Commission was subsequently formed.

Later that decade the initiative passed to the federal government. As railroads commonly cross state boundaries, Article I, Section 8 of the ***United States Constitution gives the*** federal government powers to regulate commerce between states. An important implication is that federal laws take preeminence over state laws for interstate movements. The railroads became the first industry to be economically regulated by ***the*** federal government ***with the*** passage of ***the Interstate*** Commerce ***Act*** of 1887. The first federal safety regulations followed six years later. After a series of legal challenges, the United States Supreme Court ruled in 1915 that the constitutional powers of the federal government applied to safety as well as economic regulations ***(Southern Railroad v. Railroad Commission of Indiana (236 U.S. 439 (1915)).***

The federal ***Safety Appliance Act*** of 1893 required the use of the Westinghouse air brake on locomotives and Janney-type semiautomatic couplers. Both devices had been in existence since the late 1860s but had not been uniformly adopted. There had been pressure to improve braking for some time. Some states, such as Iowa, had taken the lead by requiring the Westinghouse brake in the 1880s. There was also concern that the lack of uniformity between **cars** had led to the continued use of simple pin-and-link couplers which caused a high levels of casualties to employees who had to go between cars to engage them. Subsequent to the widespread use of the Janney coupler, the number of employees injured in switching operations fell by **three-quarters** between 1891 and 1915 (Clark, 1974).

About the same time the industry introduced some self-regulation for purely commercial reasons. Even in the mid-1880s there were more than twenty different track gauges and each railroad had uniquely designed rolling stock. Goods that needed to travel over multiple railroads had to be transhipped between cars at places where railroads met. Consequently, there was a commercial motivation for railroads to agree on a level of standardization. In 1886 a uniform national standard rail gauge was adopted which required the shifting of rails on 15,000 miles in the south. The increased ability to interchange cars between railroads required standardization of couplers, and a commonality of components so that cars could, if necessary, be repaired far from home. The Master Car Builders Association, which had been founded in 1867, drew up a model interchange agreement and developed rules on the design and condition of cars that were binding on all subscribing railroads. Signataries to interchange agreements were obliged to use the Janney coupler in 1887, and the Westinghouse automatic brake in 1888. These industry requirements predated the ***Safety Appliance Act*** by some five or six years.

The need for standardization resulted in similar cooperation between railroads to set standards for: motive power design (through the American Railway Master Mechanics Association founded in 1868); painting and marking of cars (Master Car and Locomotive Painters Association from 1870); time zones (General Time Convention of 1883); recommended operating ***rules (the Standard Code of Railroad*** *Operating* ***Rules*** of 1887); and telegraph train orders (1887). It is interesting to note that it was not until 1918 that Congress followed the lead of the railroads in establishing national time zones.

1900-1910: MORE REGULATIONS *AND SAFETY FIRST*

By the end of the nineteenth century technological advances had improved safety immensely as compared with the time of the civil war. These advances included the introduction of steel rail **(1865),** continuous air brakes **(1869),** interlocking of signals and switches **(1870),** track circuits **(1872),** steam train heating **(1881),** and electric train lighting (1882). In the first decade of the new century steel cars came into widespread use which reduced the chances of telescoping and fires following a derailment or collision.

Despite these improvements there was a great public outcry at the start of the century (Clark, 1974). The main reason was the expansion of the railroads which resulted in increased frequency and visibility of accidents. Between 1890 and 1910, train miles increased by seventy percent and passenger miles by 175 percent. While fatality rates did not increase over the period, the absolute number of casualties did. Total annual fatalities increased by half from 1890 to 1910 (figure 2.1). Over the same period the number of non-employee injuries increased threefold (figure **2.2),** and the number of employee injuries increased fourfold. Clark notes that casualties were much higher in the United States than on comparable railroads in Europe.

Consequently, a series of Acts was introduced to deal with the perceived safety problems. These Acts essentially governed safety for the following sixty years. The Acts dealt with five main areas: accident reporting, specification of safety equipment, transportation of explosives, hours of work, and financial responsibility to injured employees and shippers whose freight was damaged.

The Accident Reports Act of 1910 required railroads to report all fatality, injury and property damage accidents to the ICC. The ICC was also given powers to investigate serious railroad accidents.

A group of Acts specified items of safety hardware and equipment. The existing ***Safety Appliances Act*** was extended and amended a number of times to require air brakes on cars as well as locomotives, standardize the location of handholds and steps on rolling stock, and legislate rules on brake inspection, testing and maintenance. ***The Block Signal Systems Act*** of 1906, ***Safety Devices Testing Authorization Act*** of 1908, and ***Signal Inspection Act*** of 1920 allowed for research and then implementation of automatic signaling and interlocking. ***The Ashpan Act*** of 1908 required steam locomotive ashpans that could be emptied without needing an employee to go under the locomotive. ***The Locomotive Inspection Act*** of 1911 required boiler inspections. While boiler explosions rarely killed the traveling public, they were a leading cause of employee casualties. In the eighteen years after the Act the number of deaths and injuries due to boiler failures fell by ninety percent (Clark, 1974).

The federal government had been concerned about the dangers of the storage and transportation of explosives since the civil war. These laws were updated and expanded as new 'industrial processes led to the manufacture or extraction of new hazardous chemicals and gases. The railroads were affected by a series of Acts: the ***Transportation of Explosives Act*** of ***1908, Transportation of Explosives and Other Hazardous Materials Act*** of 1909, and ***Explosives and Other Dangerous Articles Act*** of 1960. These laws are quite general, and prior to 1967 the authority for devising specific rules and the implementation of these rules were delegated to the industry through the Association of American Railroads' (AAR) Bureau of Explosives.

The government was also concerned that employees were working excessive hours, and that fatigue was a major source of operational errors. ***The Hours of Service Act*** of 1907 established a limit of sixteen consecutive working hours in twenty-four for those operating trains, and nine to thirteen hours on duty in twenty-four for dispatchers. Following the Act the average work week for employees fell from sixty-one hours in 1916 to forty-nine hours in 1923 (Clark, 1974).

Railroads were also given financial incentives to improve safety. The ***1906 Carmack Amendment*** to the ***Interstate Commerce Act*** required railroads to compensate freight shippers for "full loss and damage" if their goods were lost or damaged in transit. Injured railroad employees were also given the legal right to obtain compensation from their employer by filing a tort claim under the ***Federal Employers' Liability Act*** of 1908. Previously, injury costs had been borne by the employee either personally or through employee-supported mutual aid societies. The requirement that occupational injury claims should be settled by torts was in contrast to the "no-fault" system of workers' compensation that subsequently emerged in other industries. This unusual feature of railroading persists to the present day.

Not surprisingly, railroads became much more concerned with encouraging safe practices on the job and ensuring that employees were properly trained (Aldrich, 1992). The Chicago and North Western Railway started the first accident prevention, or ***Safety First,*** program in 1910, following from the principles pioneered by U.S. Steel in 1906. In 1918 all of the large Class I railroads were required by the government to adopt such programs, and encouraged to join the **Steam** Railroad Section **of** the National Safety Council. As a result, employee injuries rates fell by threequarters between 1920 and 1940. Only the iron and steel industry could claim a larger improvement in employee safety.

1970: COMPREHENSIVE SAFETY REGULATION

Between 1920 and 1960 accident rates improved considerably, and the industry was largely left to self-regulate. Technical committees of the **AAR** and the National Safety Council managed the initiatives arising from ***Safety First*** programs. There were technological advances including the Sperry broken rail detector car **(1927),** ultrasonic track inspection **(1959),** centralized train control **(1927),** and the automatic inductive train stop (1933). By 1960 passenger services were in serious decline and it seemed that the future of the railroads was as a freight carrier, which one might imagine would reduce the pressure for government oversight.

However, then came the disastrous decade of the 1960s. The improvement in safety witnessed in previous decades was reversed. Employee fatality and injury rates increased by sixteen percent and seventy-five percent respectively between 1960 and 1970. The major cause was the decline in railroad finances, especially in the East and Midwest with the bankruptcies of the Penn Central, Rock Island and Milwaukee Road, which lead to considerable deferred track maintenance. The rate of accidents per ton-mile caused by track defects doubled between 1966 and 1974 (Office of Technology Assessment, 1978). Simultaneously with the decline in track maintenance was the introduction of larger freight cars. This lead to a sharp rise in derailments due to broken rails **(NTSB,** 1974).

These derailments become more of a public concern because of the expanded carriage of hazardous materials. While the railroads had always carried explosives and munitions, they now carried flammable liquids, pressurized liquified gases, and corrosive liquids. In 1969 there was a series of accidents where tank cars ruptured with disastrous consequences for people who lived next to the railroad.

There was consequently agitation for some government intervention, not least from the labor unions whose members' jobs were under threat as railroads attempted to improve their financial situation. The unions argued, for example, that the increase in collisions and derailments was linked to the removal of firemen from diesel locomotives in the mid-1960s. (See the academic paper by Fisher and **Kraft** (1971) whose econometric argument, in the fullness of time, appears to be misleading.)

This was an era when government was probably receptive to expanded safety powers. The FRA was created in 1967, and assumed the powers of the ICC's Bureau of Railroad Safety. Cynical readers might suspect that the FRA was ***looking*** for new powers to consolidate its position and justify expansions in staffing. It is also notable that the late 1960s was the highpoint of "big government" with the formation of powerful federal commissions with safety missions: the National Highway Traffic Safety Administration, the Occupational Safety and Health Administration (OSHA), the Environmental Protection Agency (EPA), the Consumer Product Safety Commission, and the Nuclear Regulatory Commission.

An alternative viewpoint that has been suggested to me by then-senior officials of the FRA was that a major motivation was a desire to make a preemptive strike to prevent **OHSA** from taking a lead role in regulating railroad safety. OSHA is forbidden **from** intervening if other government agencies have already established safety regulations. The understandable reaction of the FRA was that it was better for safety regulation to be decided on by people familiar with the industry rather than by outsiders.

The Congress was also interested in railroad safety. Public pressure prompted investigations by Congressional committees. These committees concluded that the vast **majority** of accidents, especially those involving track defects, were caused by factors that were not covered under existing statutes. There was also concern that the industry was largely self regulated. The Congressional Research Service (1979) quotes a congressional committee's displeasure that "the ICC **[had]** practically turned the hazardous materials transportation safety program over to **AAR's** Bureau of Explosives. "

The result of FRA and congressional initiatives ***was* the *Federal Railroad Safety Act*** of 1970 which gave the FRA rulemaking authority to:

> "promote safety in all areas of railroad operations and to reduce railroad related accidents, and to reduce deaths and injuries to persons and damage to property caused by accidents involving any carrier of hazardous materials. "

The **FRA's** first order of business was to set up a committee to decide on recommended track standards. Six categories of track were established each with a maximum allowable speed. Detailed engineering specifications were written to define each category of track. The FRA was given powers to hire track inspectors to enforce these standards, and assess penalties for noncompliance.

The FRA then dealt with defective rolling stock by taking the existing AAR rules on interchange of freight cars and writing those parts dealing with **safety-**related equipment into federal law. The regulations deal with defining defects in wheels, axles, ***bearings,*** trucks, bodywork, couplers and cushioning. Again, the FRA hired inspectors to randomly inspect cars, write citations and assess penalties. Subsequently, rules were also introduced on various aspects of diesel locomotive design, and the frequency with which certain components should be inspected.

The concern about accidents caused by human factors was addressed in the ***Federal Railroad Safety Authorization Act*** of 1976 which promulgated rules to protect workers going between cars. **The *Rail Safety Improvement Act of 1988*** introduced qualification requirements for railroad engineers. Previously qualifications had been decided by collective bargaining between railroads and unions.

The safety of railroad engineering workers was further affected by the ***Occupational Safety and Health Act*** of 1970. The objectives were "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions. " Employers are given a duty to furnish "employment and a place of employment which are tree from recognized hazards that are causing or are likely to cause death or serious physical injury to his employees." As already discussed OSHA regulations only apply when regulations set by other government agency are absent. Under an agreement between the FRA and OSHA in 1978, it was agreed that **OHSA** regulations are only applicable to the maintenance shop operations (except when trains are moving) and offices.

The problem of fatalities at highway grade crossing, which in 1970 were almost three times as numerous ***as they*** are now, ***was*** addressed by ***the Highway Safety Acts*** of 1973 and 1976, and ***the Surface Transportation Acts*** of 1978 and 1982. These Acts authorized ninety-percent federal funding to states for public grade-crossing improvements such as the installation of flashing lights and gates. This is commonly referred to as the ***Section*** I30 program. While the federal government has a substantial funding role, decisions on which crossings to improve and what types of warning device to install are left with individual state highway authorities. The government and the railroads instituted a public information effort under the ***Operation Lifesaver*** banner to educate the public on the dangers of highway-rail crossings. These programs have been very successful in reducing the risks at grade crossings.

An area of considerable **rulemaking** and congressional action has been the transportation of hazardous materials. In 1967 the DOT set up a Hazardous Materials Regulations Board (now part of the Research and Special Projects Administration) to deal with inter-modal shipments of hazardous materials, and make rules on packaging and placarding. The major piece of legislation to support these activities ***was the Hazardous Materials Transportation Act*** of 1974 which brought together the fragmented provisions already in effect, and provided for federal preemption of state laws. Later Acts such ***as the Hazardous Materials Transportation Uniform Safety Act*** of ***1990,*** and ***Sanitary Food Transportation Act*** of 1990 imposed greater requirements on both the shipper and the railroad to adequately placard cars, and provide detailed information for firefighters on the consists of trains containing hazardous materials, and the recommended way to respond to specific hazards.

Concurrently with the increased safety regulation, there was a reduction in economic regulation. ***The Railroad Revitalization and Regulatory Reform Act*** of 1976 allowed the ICC to exempt some commodities from price regulation. In response to industry complaints that the forced retention of lines which had long ***since*** lost all passenger and most freight service was a financial drain, the procedures for abandonment of uneconomic branch lines were made easier.

The ***Staggers Act*** of 1980 exempted even more commodities from regulation and made price regulation much looser. The ICC retained powers to review rates for shipments, such as coal, where rail is the dominant form of transportation. Private contracts between railroads and shippers were allowed for the first time since 1887. The Act also encouraged the shedding of branch lines by large railroads by transferring them to small companies. With the removal of most of its regulatory powers, the ICC was disbanded by ***the ZCC Termination Act*** of 1995. The remaining railroad powers concerning approval of abandonments and mergers, and the review of bulk shipment rates were transferred to a new Surface Transportation Board within the DOT.

Subsequent to deregulation the railroad industry has flourished. In the 1970s the average rate of return on equity was less than two percent. It grew to six percent in the **mid-1980s** and to twelve percent in the **mid-1990s (AAR,** 1997). Traffic has expanded with the number of revenue ton-miles increasing by **forty-**seven percent between 1980 and 1996, albeit that traffic had reversed a longstanding decline starting in the 1960s. What is more important, the railroads have stabilized, and even somewhat increased, their market share of domestic **freight** movements at about forty percent despite strong competition from trucks, barges and pipelines.

4 HOW SAFE ARE AMERICAN RAILROADS?

How safe are American Railroads? That question can **only** be answered by making comparisons with other types of risks. This chapter compares employee risks in railroads with those in other industries, passenger risks across modes of transportation, railroads versus other hazards of modem life, and United States to railroads to those in Canada and Great Britain.

OCCUPATIONAL RISKS

Table 4.1 presents 1995 data on occupational risks for a number of industries. The rate of fatalities and of injuries that require at least one lost workday are shown as a rate per 100,000 employees. The industries are shown in descending order of

Table 4.1: Fatal and Lost-Workday Injuries per 100,000 Employees 1995

	Fatalities	Injuries
Agriculture, Forestry, Fishing	48.2	4200
Taxis, School Buses	29.2	8000
Water Transportation	29.2	4800
Mining	26.8	3800
Trucking & Warehousing	24.6	6900
Construction	20.6	4800
Railroads	**12.8**	**3200**
Utilities	10.1	3500
Aviation	9.7	7900
Manufacturing	3.8	4600
Wholesale and Retail	3.4	3100
Services	2.4	2700
Finance, Insurance, Real Estate	1.9	900
Communications	1.8	1500

Source: Bureau of Labor Statistics **(1996a,b)** fatality risk. Compared with other occupations that require work out of doors and involve heavy moving machinery, the occupational risks of railroading are at the lower end of the scale and are comparable with working for a utility company. Workers in the trucking, maritime and taxi industries have fatality rates twice that of railroad workers.

While the overall average occupational risks in railroads are relatively low, the risks vary by type of employee. In the first chapter it was calculated that train crews face the most risk with a fatality rate of 23.6 per 100,000 employees. This would place the occupational risk to train crews as equivalent to the ***average*** risk to workers in mining or trucking. However, given that the mining industry also has a mix of different classes of employees who face different risk levels, train crews face less risk than people working at the mine face.

PASSENGER RISKS

Table 4.2: Passenger Fatalities per Billion Passenger Miles 1986-1995

Automobile (1990-95)	8.29
Railroad	0.81
Bus (school, transit and intercity)	0.23
Commercial Aviation	0.21

Source: National Safety Council (1997)

Major transportation disasters with large loss of life occur randomly and rarely, so an appropriate view of the risks of different modes can only be calculated as an average over a lengthy time period. Table 4.2 shows the passenger fatality risk per billion passenger miles for different modes of transportation calculated for the period 1986 to 1995. The railroad fatality rate of 0.81 per billion passenger miles is three to four times worse than buses and commercial aviation, but ten times safer than driving.

GENERAL PUBLIC HAZARDS

Table 4.3 compares the fatality risks of railroads versus other common hazards found in society. This table only considers hazards that the public faces at home and in public places and excludes occupational fatalities. The 600 fatality figure for railroads represents deaths to trespassers, passengers on trains, passengers at stations, pedestrians at grade crossings, and those adjacent to the railroad. Highway-user fatalities at grade crossings are included in the 20,000 people killed in private automobile driving.

Even when one includes fatalities at grade crossings, the approximately 1,000 people killed in accidents involving railroads each year represent a risk that is only slightly more than the risk of drowning in a home swimming pool or bath.

Table 4.3: Non-Occupational Fatalities 1996

Homicide	**25,000**	Firearms accidents	1,300
Private auto driving	**20,000**	Aviation	800
Falls	13,500	**Railroads**	**600**
Suffocation & poisoning	10,300	Boating	500
Drowning	3,400	Floods	110
Fires	3,100	Lightning	90
		Hurricanes & tornadoes	70

Source: National Safety Council (1997)

INTERNATIONAL RAILROAD COMPARISONS

There is no publication that permits easy and extensive comparison of international railroad safety data. However, table 4.4 contains a comparison between the United States in 1994, Canada in 1994 and Great Britain in 1993/94. The fatality and injury rates are expressed as an index with the United States equal to 100. Canada provides the best peer comparison with the United States because of similar terrain and the predominance of freight traffic. The British railway system is primarily a passenger system and the data, unlike the United States and Canada, includes mass transit. .

Employee casualty rates in the United States are slightly higher than in Canada and twice those in Great Britain. One explanation for the lower British casualty rates is that as a passenger railroad, there are more people in customer service functions that are removed from the danger of moving trains.

Table 4.4: International Comparisons (United States = 100) for USA (1994), Canada (1991-94 average) and Great Britain (1993/94)

		Fatalities			Injuries		
Casualty Type	Exposure Measure	USA	CAN	GB	USA	CAN	GB
Employees	employee hours	100	83	45	100	89	52
Passengers	passenger miles	100*	198	102	100*	159	713
Trespassers	population	100	98	111	100	84	89
Grade Crossings	motor vehicles	100	111	19	100	143	26

* Average for 1980-1996

Sources: United States: FRA (1995a,b), FHWA (1995), Department of Commerce (1995). Canada: Transportation Safety Board of Canada (1995), Statistics Canada (1995), American Automobile Manufacturers Association (1996), Human Resource Development Canada (1998). Great Britain: Health and Safety Executive (1995).

Comparisons of passenger casualties are difficult because due to the random nature of passenger train accidents that result in large loss of life. In 1994 the British passenger fatality rate is comparable with the seventeen-year average for the United States. The Canadians in the early 1990s had a passenger-fatality rate twice that of the United States. Britain does have a high rate of passenger injuries. A major contributing factor in Britain is the widespread use of hinged passenger car doors that open outward.

There is a quite remarkable similarity among the three countries in the propensity of the population to trespass on the railroad, and get struck by a train. This similarity is despite the fact that Britain's railways are largely fenced.

The most striking difference between the countries is the risk of grade crossing fatalities. The fatality risk per vehicle registered in America and Canada is five times higher than in Britain. Unlike North America, the British system was built with extensive grade separation, which reduces the exposure to highway-rail collisions.

5 RISK EVALUATION

The previous chapter presented actuarial evidence on the risks of railroading and compared them with other hazards in society. However, no judgment was drawn as to whether these risks were "acceptable" or "too high." The purpose of this chapter is to provide a bridge between the actuarial risks and understanding the public policy response to risk. While public policy is influenced by actuarial risk calculations, it is largely swayed by public opinion. There is now a large body of literature by psychologists concerning the way in which people form opinions about the magnitudes of risk, and whether they find the risks acceptable. There is also a literature by economists and political scientists on the appropriate public policy response to different levels of risks.

Throughout this chapter, reference will be made to annual fatality risks expressed as a probability. To provide a frame of reference here are some railroad fatality probabilities:

Working as a train crew member for one year (based on average fatality rate for 19904)	1 in 3,500
Working on the railroad for a year (all employment categories) (based on average fatality rate for 19904)	1 in 6,000
Crossing a highway crossing with passive warning devices twice a day for a year:	1 in 185,000
Commuting by train twenty miles a weekday for a year (based on average fatality rate for 1990-6)	1 in 215,000
Annual risk per head of population from trespassing or as a bystander	1 in 530,000
Crossing a highway crossing with active warning devices twice a day for a year:	1 in 790,000

And as a way of comparison, other fatality probabilities are:

Working in agriculture, forestry or fishing for a year	1 in 2,000
Driving 20 miles (round trip) to work for a year	1 in 22,000
Working in a wholesale or retail trade for a year	1 in 30,000
Annual non-occupational risk of fire	1 in 85,000
Annual risk of floods, storms and lightning	1 in 1,000,000

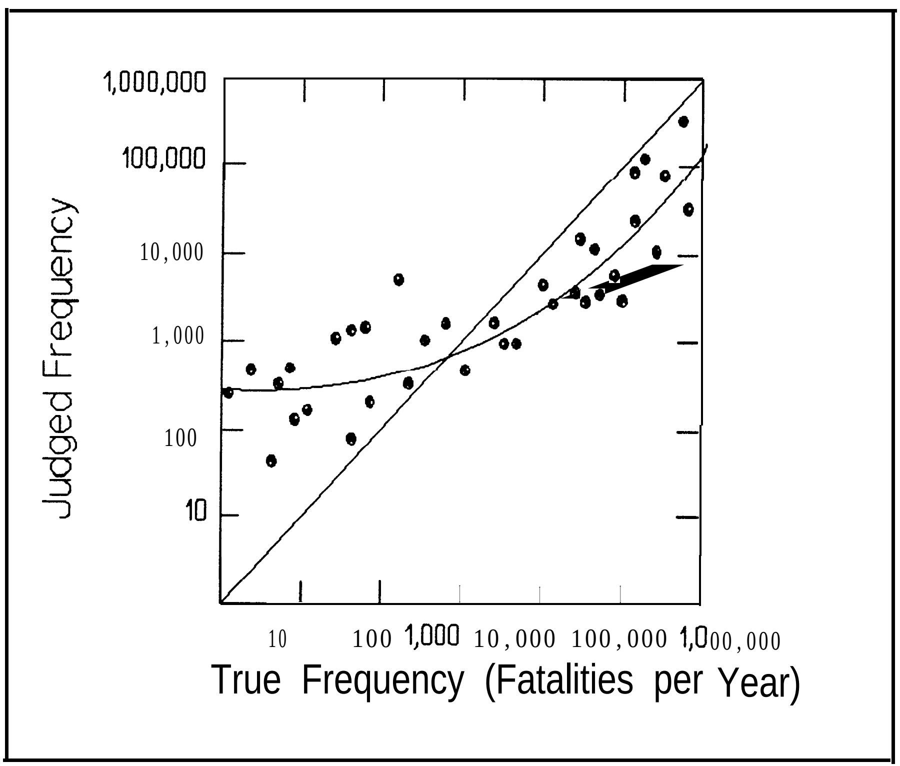
PUBLIC PERCEPTION OF RISK PROBABILITIES

Empirical experiments by psychologists have found that lay people are unable to accurately judge the frequency of hazards that they face. Moreover, there are some systemic biases in the way that people misperceive risk frequencies. The seminal work is **Lichtenstein** et al. (1978). Lay people were told the actual annual number of fatalities in America for either electrocution (about 1,000 per year) or motor vehicle accidents (50,000 per year). The respondents then had to give their estimates for the annual number of deaths for forty other lethal events. The plot of results is shown in figure 5.1.

On the horizontal axis is shown the actual annual number of fatalities, and the vertical axis the geometric mean of the respondents' judged frequency. Hazards that fall below the **45°** line are those which respondents judged were less risky than **in** reality, whereas those hazards that lie above the **45°** line are whose for which respondents overestimate the real risk.

The most striking result, which is termed ***primary bias*** by the psychologists, is the tendency to overestimate infrequent causes of death (for example, botulism, floods and tornadoes) while underestimating more frequent causes (for example, heart disease and cancer). This is represented by the curved line of best fit shown

Figure 5.1: Judged Versus True Frequency of Death



in figure 5.1. The 'crossover' point where perception and reality were closest was for hazards with a probability of about 1 in 225,000 such as appendicitis. The researchers concluded that the observed bias was due to the nature of the hazards studied and not associated with potential psychometric problems such as a reticence to use large or small numbers.

Of course, most of the hazards do not lie exactly on the line of best fit. For example both botulism and risks from smallpox vaccinations are both low probability events, the frequency of which are generally overestimated by lay people. However, the risk of botulism is greatly overestimated, while that from the smallpox vaccination is overestimated to a lesser extent. The same is true when two high probability events such as homicide and diabetes are compared. The frequency of both is underestimated but that of diabetes is underestimated to a greater extent than homicide.

A second effect, known as secondary *bias,* represents these deviations away from the line of best fit which captured the primary bias. Lichtenstein et al. observe that hazards with an upward secondary bias are "generally dramatic and sensational whereas [hazards with downward secondary bias] tend to be unspectacular events, which claim one victim at a time." Spectacular multifatality accidents receive extensive media coverage (Combs and Slovic, 1979), which Johnson and Tversky (1983) found affected peoples' "mood" and led to a heightened perception of risk.

Highway grade crossings were one of the hazards studied in Lichtenstein et al.'s work. At that time these accidents claimed about 1,500 fatalities a year. The study's respondents judged that these accidents caused between 600-800 fatalities per year, or about half of the real death toll. Not only did the primary bias lead to an underestimation of risk, but downward secondary bias was present as well because most grade crossing fatalities occur in events where a single life is lost and do not receive extensive media attention.

Table 5.1 shows the most likely biases applicable to contemporary railroad risks. Today the risk to grade crossing users would fall close to the crossover in primary bias, where we might expect perception of risk to match reality. The risk to trespassers falls in the same range. However, the risk to passengers on trains, and to third parties from hazardous materials spills, is much smaller so we would expect that people bias upwards their risk perceptions due to both primary bias and upward secondary bias caused by the extensive press reporting of any incidents.

PUBLIC ACCEPTANCE OF RISK

The accuracy of the perception of the true magnitude of risks is only part of the story. Even if risk was accurately known, the public would accept some hazards willingly, and express consternation about others. People recognize that there are risks associated with many activities in life, and are accepting of some risk in order to gain certain benefits. For example, people accept the risks of driving in order to gain mobility and freedom. However, not all hazards are accepted equally.

Table 5.1: Biases in the Perceptions of Railroad Risk Probabilities

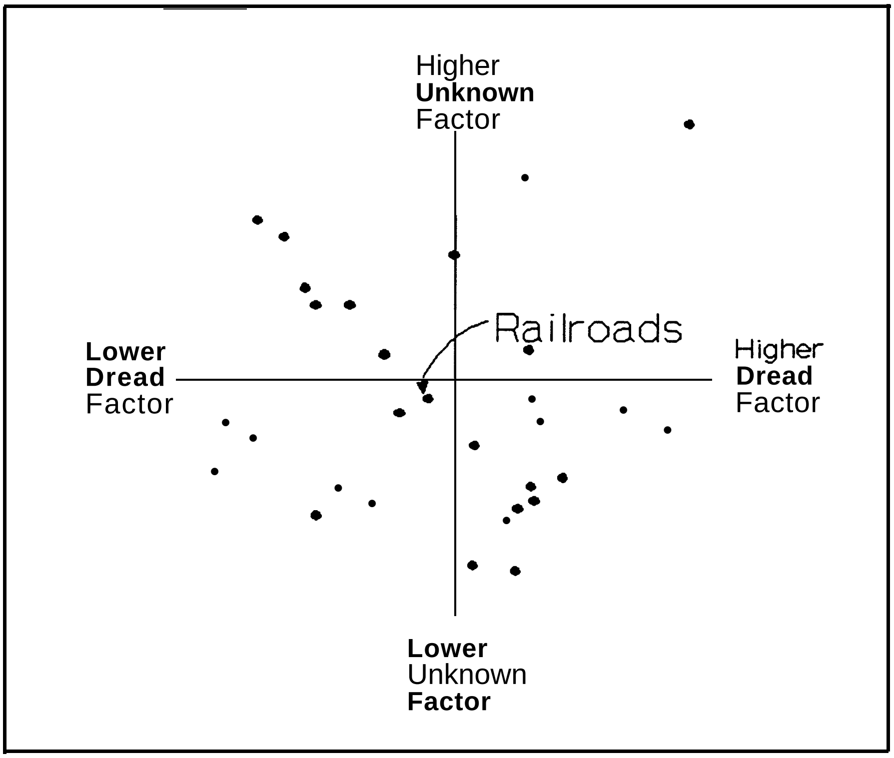
		Secondary Bias	
		Downward	**Upward**
Primary Bias	Downward		
	Neutral	Highway Crossings, Trespassers	
	Upward		Passenger Trams, Hazardous Materials Releases

Psychologists have analyzed peoples' acceptance of different types of **hazards.** Fischoff et al. (1978) asked respondents from the League of Women Voters to indicate the relative benefits and risks of thirty technological hazards which included **railroading.** Railroads were judged to have high benefits and relatively low risks. Benefits were judged to be comparable with those derived **from** driving, vaccinations, and the existence of fire and police departments; while the risks were comparable with those from food coloring and preservatives, college football, and lawn mowers. When asked to indicate which hazards required societal action to reduce the risks, the respondents did not give a high priority to railroads. Alcoholic beverages, handguns, motorcycles, automobiles, nuclear power, pesticides, and smoking were the hazards for which the respondents demanded action to reduce risk.

Fischoff et al. then attempted to gain a further understanding of the attitudes to risk by asking respondents to rate each of the hazards using nine different characteristics: whether people are exposed to the hazard voluntarily or involuntarily; whether death is immediate or delayed; whether the hazard is known to the potential victim; whether scientists understand the risks; whether the victim could have mitigated an accident due to their personal skill or diligence; whether the hazard is new or old; whether the **hazard** claims multiple victims at one time; whether the hazard is a common one or a "dread" hazard; and whether the outcome is certain to be fatal or not. In general, railroads fell very close to the mean response in each category, except that it is regarded as an "old" **hazard,** and is perceived as claiming multiple victims at one time.

Of course, many of these characteristics are collinear with each other. Factor analysis has been used to conclude that attitudes to risk are dependent on two major factors. The first is whether the probability and consequences of an accident were

Figure 5.2: Location of Hazards in Unknown - Dread Factor Space



known in advance. This factor is typically called the ***unknown factor. The*** second is that certain types of accidents engender ***dread.*** Dread is largely determined by the voluntariness of the exposure to the hazard, and whether potential victims can control the outcome of risky situations. Figure 5.2 shows a plot of the unknown and dread factor scores for the hazards investigated by Fischoff et al. The higher the scores on both the unknown and dread scales, that is to say moving toward the top right of the graph, the less accepting the public is of the hazard. Railroads appear to fall right in the middle of the graph. Further studies by the same authors based on the responses of college students and professional risk assessors also placed railroads firmly in the center of the graph (Slovic, Fischoff and Lichtenstein, 1980, 1985).

The above studies only considered the risks of railroads in general and did not consider the different components of the annual fatality toll. There is evidence that the respondents were not familiar with the risk of railroads. At the time the studies were undertaken annual railroad fatalities where about 1,900 whereas the respondents in Slovic et al. (1980) estimated that annual fatalities in a typical year were 200, which could rise to between 330 and 600 in a particularly "disastrous" year. Respondents were clearly unfamiliar with the fact that the vast majority of railroad fatalities are to trespassers and highway-crossing users, and that there is little year-to-year variation, outside of the overall downward trend over time, in fatalities to these groups.

Using the principles developed so far in this section, I have tried to classify in table 5.2, the most likely unknown and dread scores for five types of people exposed to railroad risks. As one moves toward the bottom right of the table, people become less accepting of risk.

Table 5.2: Classification of Railroad Hazards by Acceptance Factors

		Dread	
		Low	High
Unknown	Low	Trespassers, Highway Crossings, Employees	
	Medium		Passenger Trains
	High		Hazardous Materials Releases

Acceptance by Trespassers and Highway-Crossing Users

I have already argued that most people who trespass on the railroad, or are negligent at grade crossings, are well informed about the possible risks. They undertake these risks voluntarily, and are usually confident that their own diligence and skill can save them in the event that a train shows up. The consequent low dread and unknown scores would explain the lack of an outcry about fencing the railroad to discourage trespassers, and the general acceptance of most grade-crossing risks. This lack of an outcry is even more remarkable given the large number of annual fatalities to these two classes of people.

Acceptance by Employees

Employees are generally assumed to voluntarily choose their occupation, and would very quickly become familiar with the types of risks they are exposed to and the magnitudes of those risks. Moreover in a perfectly functioning job market, employers in risky occupations would have to pay a premium wage to attract staff, and would attract workers who are comfortable with the risks. Therefore, most risk analysts acknowledge **that** employees will **accept** more risk **than** consumers or third parties.

Acceptance by Passengers on Trains

Passengers on trains are, in a sense, riding voluntarily, but they are certainly not in control of the situation. People are less willing to accept risk when they put their lives in the hands of an airline pilot or locomotive engineer than when they are behind the wheel of their own automobile. Jones-Lee and Loomes (1995) found that subway travelers in London place a risk premium of fifty percent on subway travel compared with automobile travel.

The psychologists claim that hazards that claim multiple victims at one time engender more dread than **hazards** that claim their victims one at a time. This ***scale*** effect has been actively debated in the literature. Jones-Lee and Loomes (1995) dispute whether in practice such a scale effect exists based on survey work in London. However, I would claim that it does. By this I am not saying that the public is irrational in thinking that a single accident claiming twenty-five lives is worse than twenty-five separate accidents claiming one person each. Rather I am claiming that large accidents provoke different emotions than smaller, more routine, accidents. And these emotions affect both the unknown and dread factors.

Major passenger train disasters are usually caused by a combination of several contributing factors, which may be mechanical, human factors, environmental, managerial and public policy related. This is in contrast to most trespasser and grade crossing accidents where the "facts" are usually simple, straightforward and widely understood. Thus the reporting of most **major** railroad accidents will cause many people to reevaluate whether they know and understand the risks of railroads, and the resultant uncertainty will cause apprehension.

It is not surprising that the public reacts to railroad passenger accidents in a far more exaggerated way than the safety record would suggest. Indeed the railroads may consider it fortunate that the changing role of railroads away from passenger to freight transportation has decreased the frequency of passenger train accidents, and hence reduced the extent of the publicity and public concern.

Acceptance by Third Parties

Third Parties are people who live or work adjacent to the railroad line and might be affected by a collision or derailment, especially one that leads to a release of hazardous materials. Though the statistical probability of such an event is very small, the public is very fearful and unaccepting of the risks. A contributing cause to the fear is that people are generally unaware of the magnitudes of the risks resulting in a high unknown risk-acceptance factor. While local residents may have a reasonably accurate view of the probability that a derailment may occur, they are not aware of what exactly is in the tank cars, how volatile those contents might be, or what will happen if a release occurs. Given that neither the railroads nor shippers appear to be particularly keen on making such information generally available, the public can only fear the worst based on television pictures of fireballs, and news reports about small towns evacuated for weeks due to leaking liquid petroleum gas tank cars.

People are less accepting of risk if they cannot appreciate the benefits that the risky activity confers. Traditionally the railroad **conferred** many economic benefits on the towns that it passed through. Nowadays the passenger station and public **freight** depot have closed, and the local residents perceive that there are few local economic benefits **from** the railroad. People are also less accepting of risk if they feel that they are exposed to the risk involuntarily. Traditionally only people living right next to a railroad would be affected by a derailment, and people could choose to live further away. The increased shipment of hazardous materials has meant that the consequences of derailments in the form of gas clouds and fireballs may affect people living some distance from the tracks. It is worth remembering that many small rural towns still have **land-use** patterns centered around the railroad tracks.

PUBLIC POLICY ON RISK APPRAISAL

The logical extension of the discussion in the previous two sections is to ask how public perceptions and reactions to various **hazards** are translated into public policy. While a public outcry about specific **hazards** can undoubtedly affect the agendas of elected officials, the power lies with government officials. If action is required in response to a risk, the legislature usually sets broad general goals for dealing with the hazard. The promulgation of the specific rules and regulations to implement public policy is then left with the various agencies of the administrative branch of government (Viscusi, Vernon and Harrington, 1995; Viscusi, 1996). ***The Federal Railroad Safety Act*** of 1970 is a good example. Congress laid down some general objectives and gave the FRA rulemaking powers over "all areas of railroad safety." The development of the specifics regulations was then left to the FRA.

The methodology by which the proposed regulations are evaluated is not clearly defined. The federal Office of Management and Budget is empowered by Executive Order 12291 of 1981 to review all regulations to show that the benefits exceed the costs, except in cases where any analysis would conflict with the legislative mandate of the agency promulgating the rules. This exemption primarily concerns regulations from the EPA and **OHSA** rather than the DOT (Viscusi, 1996).

A leading method for evaluating regulations is ***cost-benefit analysis.*** A major feature of cost-benefit analysis is the desire to express the valuation of **non-**pecuniary benefits and costs such as time savings and deaths and injuries avoided in dollar terms. This permits a strictly numerical comparison of benefits and costs. Transportation has been at the forefront of the development and application of **cost-**benefit analysis, and the DOT has a tradition of appraising investments and proposed regulations using it (Viscusi, 1996).

FRA manuals on conducting cost-benefit analysis have existed for some time. A manual for conducting a cost-benefit analysis of precautions for railroad safety in general dates from 1974 (Kennedy, Lloyd and Lowrey, 1974), and a manual for evaluating the provision of active warning devices at grade crossings dates from 1986 (Department of Transportation, 1986). However, cost-benefit analysis is hardly a panacea for determining the desirability of safety regulations. Any analysis requires knowledge of: the costs (both direct and indirect) of the proposed regulations; the anticipated effect on the number of accidents, fatalities, injuries and property damage; and a valuation methodology for fatalities and injuries. There are considerable uncertainties involved in all these aspects. These uncertainties result not only from deficiencies in the knowledge of economists, but also the inability of engineers to predict the effect of regulations on the probability and severity of accidents.

In these circumstances, simpler *rules* are needed. *An* alternative is ***Quantitative Risk Assessment*** where the statistical risks associated with an activity are enumerated, and some rules adopted to decide whether these risks are acceptable or not. Quantitative Risk Assessment is used in the United States, although the rules adopted are ridiculed by Viscusi (1996). For example, the EPA and the Food and Drug Administration have targets that no one should face a lifetime risk of more than 1 in 100,000 from an activity or hazard. On the basis of a seventy-year life this implies that no one should be exposed to an annual risk of more than one in seven million, which is smaller than the risk of being struck by lightning. These rules would clearly outlaw most things that we do in our daily lives.

Much more useful are the rules adopted by the British Health and Safety Executive, the equivalent of OHSA, and based on international experience and a study by the Royal Society (Evans, 1994). Risks are divided into three categories. The first category is for risks that have such small probabilities that no action is required. *These risks are* often called ***negligible*** risks, and have probabilities similar to that of being struck by lightning (ie., about one in three million). At the other end of the scale is a second category of risks that are so large that nobody should be exposed to these risks and action should be taken without regard to the financial consequences. *These risks are* described *as **intolerable** risks. Risks* that fall in the zone between these two categories are often referred as falling in the as ***low as reasonably practicable*** or ***ALARP*** region. Risks in this category should be reduced if the cost of doing so can be justified. This would seem to support the economists' approach of conducting a cost-benefit analysis on individual policy initiatives.

Evans (1995) reports that it is commonly accepted that the boundary for the intolerable category is that no employee should face an annual fatality risk of more than 1 in 1,000 and no third party should face a risk of more than 1 in 10,000. The former figure is based on the risks accepted in the most hazardous occupations such as deep-sea fishing. The rationale for the risk to third parties is less clear, and I find the 1 in 10,000 figure unconvincing. Starr (1969) found that people were 1,000 times more unwilling to accept an involuntary risk than they were a voluntary risk. This would place the boundary of intolerable risk for true third parties, such as people living adjacent to the railroad, at about one in one million a year. The 1 in 10,000 risk may be more applicable for passengers or highway grade-crossing users where the person is exposed to the hazard voluntarily and derive some economic benefit **from** riding the train or undertaking car trips that require crossing arailmad.

These concerns are reflected in the definitions of intolerable risk adopted as policy by the British Railways Board (Evans, 1995). Their policies are shown in table 5.3. Risks are intolerable, and should be reduced without regard to cost, if employees and passengers face a risk of more than 1 in 10,000 each year, highway crossing users more than 1 in 100,000, and third parties not more than 1 in one million. British Bail therefore have set a stricter standard for employee safety than the British Health and Safety Executive, and have set the level of intolerable risk from grade crossings mid-way, in terms of exponential magnitude, between that of passengers and that of third parties.

Table 5.3: British Bail's Definition of Intolerable Annual Risk Compared with Actual British and American Performance

Type of Person	UK Guideline	UK Actual	USA Actual
Employees	1 in **10,000**	1 in 18,500	**1 in 6,000**
Passengers per mile	1 in 50 million	1 in 1337 mil.	1 in 1370 mil.
Passengers per year*	1 in 10,000	1 in 250,000	1 in 215,000
Grade crossings users	1 in 100,000	?	1 in 185,000
Trespassers	no guideline	1 in **500,000**	1 in **500,000**
Third parties	1 in 1 million	**1 in 25 mil**	**1 in 6 mil**

. My calculations for a commuter travelling 20 miles each workday
Source: **Evans (1995), Health & Safety Executive (1995), FRA (1997a,b)**

Table 5.3 also contains my calculations of the current railroad risks in Britain and the United States. I have defined third parties as synonymous with the **FRA's** definition of non-trespassers, excluding those at grade crossings. The fatality rate for employees in the United States does not meet the British Bail policy, although it should be remembered that Britain's railroads are primarily oriented toward passenger travel so that there are many people undertaking station work who are not exposed to moving trains. Front line operating employees who are estimated to face an annual fatality risk of 1 in 1,500 in Britain (Evans, 1994) and 1 in 3,500 in the United States do not meet the British Bail guidelines but are not severe enough to be classed as intolerable by the Health and Safety Executive. For all other categories of people, actual risks in both Britain and the United States are lower than the British Bail definition of intolerable risk by a comfortable margin. **Indeed** the risks to third parties are so low that they would probably fall into the category of risks that are so negligible that no public policy response is required.

6 THE STORY SO FAR

This chapter provides a summary of the major issues so far. It identifies the hazards posed by railroads, assesses the casualty rates, looks at trends in those rates, makes comparisons with comparable hazards in other industries or elsewhere in society, and reflects on how people react to the hazards. The five major railroad hazards considered are (in no particular order): fatalities to highway users at grade crossings; trespasser fatalities, fatalities to train crews in collisions and derailments and during coupling operations; occupational injuries to maintenance employees; and releases of hazardous materials.

HIGHWAY CROSSINGS

The geography of North America has presented the railroads with a legacy of a significant number of grade crossings, especially in the prairie states. Grade separation is not as common as it is in Europe. Despite the prevalence of grade crossings, the risks are quite low. A daily user of grade crossings with passive warning devices faces a much lower risk than that of drowning in their own bath or swimming pool. In addition, there is clear evidence that the risk has been diminishing over time. The annual risk per highway vehicle registered is only a fifth of that in 1970.

Highway user negligence is a factor in many grade crossing collisions. In a quarter of all collisions the road user drives into the side of the train. At crossings with gates, eighty-six percent of fatalities occur when the road user drive around or through closed gates.

TRESPASSERS

Trespassers can be characterized as single adult males under the influence of alcohol. Trespassing is primarily an urban problem with many trespassers killed close to their residences. It would appear that the railroad right of way is an attractive place for people to socialize and imbibe. Almost a third of the trespasser victims are sitting or lying in the right of way at the time of impact which clearly indicates considerable negligence on the trespasser's part or suicidal intentions. It would seem that the railroads can do very little to dissuade this type of trespass. In the past few decades the number of trespasser fatalities seems to be related to changes in the population of the country, rather than by changes in railroad operations. Remarkably the propensity for people to trespass on, and become victims of, the railroad is the same whether one looks at America, Canada or Great Britain.

Despite the fact they account for more than ninety percent of the annual fatality count, there is little public outcry concerning grade crossing or trespasser fatalities. The reason is that these incidents usually cause only one or two fatalities at a time and attract little press coverage. In addition, there is a general presumption on the public's part that the victims have voluntarily assumed the risks by trespassing on the railroad, or have been negligent in their use of a grade crossing. The general assumption by grade crossing users that they can safely cut across in front of a train because of their own superior driving skills also works to reduced risk perception and increase risk acceptance.

TRAIN CREW FATALITIES

Railroads require work outdoors and involving heavy moving machinery, which clearly pose a greater risk than working in an office. However, railroad workers face job risks which are at the lower end of the scale when a comparison is made with a peer group of other transportation modes such as trucking, aviation, and the maritime industry. There is also evidence of great improvements in worker safety. Fatality rates have fallen by a third, and injury rates by two-thirds since 1980.

However, the risks vary by type of employee. Train crews, which represent about a third of the workforce, have higher casualty rates. The fatality risk of about 1 in 3,500 per year is higher than the ***average*** fatality risk in construction injuries, and approaching that in mining. The greatest risk to train crews are due to collisions and derailments, and coupling and uncoupling operations.

OCCUPATIONAL INJURIES

On average about one in eighteen employees each year will receive an injury, and about one in thirty will receive an injury that results in at least one lost workday. This injury rate is not much greater than that in wholesaling or retailing. More than eighty-five percent of injuries do not involve a moving train. Maintenance employees, both on the track and in the workshops, face the highest injury risks. There is also a prevalence of risks from falls by operations personnel.

While employees face the greatest statistical risk of any of the parties involved in railroad transportation, risk analysts have observed workers will tolerate greater risks than consumers or bystanders. This is because workers are assumed to quickly become familiar with workplace hazards, voluntarily choose their occupation, and derive direct economic benefits from exposure to the hazards in that risky occupations will have to pay wage premiums to attract staff.

HAZARDOUS MATERIAL RELEASES

Most collisions and derailments are of little concern to the general public as they involve freight trains and occur in sidings and on yard track. However, there seems to be a great fear of those small number of collisions and derailments that result in the release of hazardous materials. These materials can affect the communities surrounding the accident site due to contamination of ground water, explosion or release of poisonous gases.

The statistical risks are very low. Indeed, by the standards used by quantitative risk analysts they would be described as negligible and not require any public policy response. However, hazardous materials releases cannot be ignored by the railroad industry. The work of risk analysts has shown that people are very unwilling to accept risks to which they are involuntary third parties. The public is also less accepting of risks that they do not understand and cannot appraise true probabilities and severities. By analogy, the public is very skeptical about the risks posed by nuclear power stations despite a historical safety record that is very good.

It is a fact of risk appraisal and risk acceptance that the death of one person whose house is adjacent to the railroad may be regarded by the general public as worse than the deaths of 1,000 employees or passengers. The railroad manager, and the economist, may lament this fact and the effects that this may have on safety resource allocation. However, to the extent that the essence of free-market economics is that consumer preferences are paramount, the reality is that the public is willing to pay many times more to protect a third party than they are to protect an employee or other interested party. Moreover, these attitudes risk drive public opinion and hence the political economy in which railroads have to live.

WHAT'S NEXT?

The preceding paragraphs have given the reader an idea of the contemporary safety performance of the railroad industry, how it has changed over time, and how it compares with other hazards in society. However, the above comments do not permit the reader to conclude whether or not the railroad industry has a "safety problem" and whether it should invest more to improve its safety record. The public outcry about railroad safety over the years, which has led to considerable governmental rulemaking, might suggest that there is something unsatisfactory about the safety decisions that are made by railroad managers. But is there any substance to these concerns, or are they due to political posturing and pressure by special interests? How safe should the railroads be? What is the best way to tackle any "safety problem?" The remainder of this book is devoted to dealing with these questions.

The economist would argue that the root of answering these questions is to determine whether there is ***any failure*** in the market mechanisms that determine safety. The next ten chapters present the basic economic theory, indicate how market failure might occur, and use empirical evidence to ascertain the existence and magnitude of possible market failures in the railroad industry.

The theory can be divided into two distinct types. The first is the economics of ***bilateral accidents.*** These are accidents where the probability of an accident is influenced by the level of preventive effort undertaken by both the railroad and the other party involved in the accident. The prime examples of bilateral accidents are grade-crossing collisions, trespasser fatalities, and occupational injuries. Because the highway user, trespasser, or employee can affect the probability and severity of an accident by the level of ***care*** that ***they take,*** economic and legal theory has developed to provide all parties the correct incentives so as to minimize the societal cost of accidents. The theory of bilateral accidents is described in chapter 7, and then is applied to grade crossings, trespassers and occupational safety in chapters 8, 9 and 10 respectively.

A different theory of safety is ***used*** when ***we*** look at ***operational safety.*** Here, safety is one of the attributes of the service offered by the railroad to its passenger and freight customers. It is an attribute of service that is desired by customers but costly to provide. There will be some economic equilibrium where desire and costs are matched. This equilibrium is described in chapter 11. However, this ideal equilibrium will only occur when five conditions hold: that the railroad has no market power; customers are well informed about the level of safety offered; customers are rational in making choices about safety; railroads are not myopic in their decision making; and that accident costs imposed on bystanders are borne by ***the*** railroad. A ***market failure*** will occur when one, or more, of these conditions does not hold in the actual marketplace. Chapters 12 through 16 consider whether each of these five conditions holds in practice.

Chapters 17 through 20 then consider the various ways in which society can respond to failures in the market for operational safety. Direct safety regulation by government is only one of the possible responses. Other policy responses include legal liability, insurance and public information campaigns. These chapters consider whether full advantage has been made of the nonregulatory responses, and whether the current system of safety regulations serves a useful function.

The final chapter draws together public policy recommendations on grade crossings, trespassers, occupational injuries and operational safety that should lead to improved railroad safety at a reduced cost to society.

7 ECONOMIC THEORY OF BILATERAL ACCIDENTS

Rail-highway grade-crossing collisions, trespassing fatalities, and occupational injuries ***are called bilateral*** accidents because the level of ***care*** taken by both the railroad and the other ***party*** to the accident affects the probability of occurrence. The analysis of these accidents is a three-step process. The first step is to determine the level of care, called ***due care,*** that should be taken by both parties so as to **minimize** social costs. The second step is to observe whether the parties will, in practice, select the appropriate levels of care. If they do not, the third step ***suggests*** legal rules of ***liability*** that provide both parties with the incentives to take due care. This chapter reviews the theory. Applications to grade-crossing collisions, trespasser fatalities and occupational injuries are in the following three chapters.

DUE CARE

Accidents, and accident avoidance, impose two types of costs on society. Accidents cause personal injury and destruction of property. However, taking care to avoid accidents is also costly. For example, the installation of grade-crossing warning devices is costly to the railroad. Highway users incur costs of care because they have to slow down and observe for an approaching train before using a grade crossing. Economists argue that from a societal point of view the most preferable choice is for both parties to choose the level of care that minimizes the combination of the costs of care and expected accident costs.

The economic theory of bilateral accidents developed in the early 1970s (Brown, 1973; Diamond, **1974a,b).** The most comprehensive and readable review of the literature is given by Shave11 (1987, pages 9-21). This chapter presents the relevant theory using simple fictitious examples concerning accidents involving the railroad (RR) and another party. The other party may be thought of as either a trespasser, a gradecrossing user, or an employee.

The first example, shown in table 7.1, concerns a bilateral accident between the railroad and Party A. Each party can choose either to take no care to avoid an accident or to take care. The effort of taking care imposes a cost of five on the party taking care. The probability of an accident occurring varies between 0.06 and 0.16 depending on the level of care taken by either or both parties. The more care

Table 7.1: Example I

Level of Care		cost of **Care**		Accident Probability	Expected Accident Cost		Total cost
RR	A	RR	A		RR	A	
None	None	0	0	0.16	16	16	32
None	Care	0	5	0.12	12	12	29
Care	None	5	0	0.10	10	10	25
care	***care***	**5**	**5**	***0.06***	***6***	***6***	***22***

taken by either or both of the parties, the lower the probability of an accident. If an accident occurs, both parties suffer 100 units of damage. The expected accident cost for each party will be 100 multiplied by the probability of an accident. The expected accident costs are shown in the sixth and seventh columns. The final column shows total societal cost which is the summation of both party's expected accident costs and costs of taking care. Total costs to society are minimized in this example at a value of twenty-two when both parties take care. The level of care that a party should adopt in order to minimize total social cost is called ***due care.***

It will not always be the case that both parties must take care. Consider a second example shown in figure 7.2 involving the railroad and another party called

Table 7.2: Example II

Level of Care		cost of **Care**		Accident Probability	Expected Accident Cost		Total cost
RR	B	**RR**	**B**		RR	B	
None	None	**0**	**0**	0.16	8	8	16
None	Care	**0**	**3**	0.12	6	6	15
Care	None	**10**	**0**	0.10	***5***	***5***	***20***
Care	Care	**10**	**3**	0.06	*3*	*3*	19

B. Here the cost of the railroad taking care is ten, the cost of taking care for Party B is three, and the damages incurred by each party in an accident are fifty. The accident probabilities, conditional on the level of care taken, are the same as in the first example. The preferred societal outcome is where social costs are minimized at fifteen. Hence, due care for Party B is to take care, and due care for the **railroad** is not to take care. Note that while the probability of an accident would be lower if both parties took care, society's best interests are served when the railroad is not required to undertake the expense of taking care.

The reader will appreciate that by changing the costs of taking care, the effects of taking care on accident probabilities, and the amounts of accident damage sustained, additional examples could be provided where the optimal societal outcome is for either one, none or both parties to take care.

THE POSSIBILITY OF MARKET FAILURE

Determining due care is only half of the story. It is also **necessary** to see whether both parties will freely choose this level of care. Game theory is a powerful tool for investigating actual behavior. It uses a ***payoff matrix*** which indicates the total care and accident cost borne by each party conditional on the level of care by both parties. The payoff matrix for the first example is shown in table 7.3. Each cell of the matrix is defined by the level of care taken by the two parties. For example the upper-right cell represents the situation where the railroad takes care but Party A does not. Inside the cell in parentheses are shown the costs to the railroad and then, after the comma, to Party A. Because these are costs, they are shown as negative amounts. For example, in the upper-right cell the railroad incurs its expected accident costs of ten plus five which is the cost of taking care, and Party A only bears its expected accident costs of ten.

The matrix can be used to try to determine whether each party will act in a consistent way. In example I, the railroad will always choose to take care, irrespective of the decision of Party A, because it prefers -15 (at top right) to -16 (at top left), and -11 (bottom right) to -12 (bottom left). Party A will always choose

Table 7.3: Example I's Payoff Matrix With No Liability

		Railroad	
		No care	**Care**
Party A	**No Care**	**(-16,-16)**	**(-15,-10)**
	Care	**(-12,-17)**	**(-11,-11)**

Table 7.4: Example II's Payoff Matrix With No Liability

		Railroad	
		No Care	**Care**
Party B	**No Care**	**(-8,-8)**	**(-15,-5)**
	Care	**(-6,-9)**	**(-13,-6)**

not to take care, irrespective of what the railroad decides, because -16 (top left) is preferable to -17 (bottom left), and -10 (top right) is preferable to -11 (bottom right). Party A chooses to do this because the cost of taking care exceeds the resulting change in its expected accident damages. Therefore, in actuality the railroad takes care and Party A does not. A comparison of this equilibrium with table 7.1 indicates that such a choice of care will result in a total societal cost of twenty-five. Society is worse off than if both parties had chosen to take care and imposed a cost on society of only twenty-two. A ***market failure*** has occurred.

Market failure also occurs in example II. In actuality, as shown in table 7.4, the railroad will choose not to take care, irrespective of the actions of Party B, because it prefers -8 to -15, and -6 to -13. Party B will choose not to take care because it prefers -8 to -9, and -5 to -6. The equilibrium will impose sixteen units of total costs on society. Had Party B chosen to take care, total social costs would have been fifteen. Party B does not take care because it weighs the three-unit cost of taking care against a reduction in its own expected accident cost of only two. Party B does not take into account in its decision that taking care will also save two units of expected accident cost to the railroad.

It would be inaccurate to claim that a market failure always occurs. For example, in situations where the costs of taking care are small compared with the accident costs that each party would incur, both the railroad and the other party would correctly choose to take care and societal costs will be minimized. However, there is a high likelihood of market failure in those cases where the consequences of one party's actions impose substantial accident costs on the other party.

LEGAL RESPONSE TO MARKET FAILURE

In response to the possibility of market failure, society has developed ***tort liability*** laws which aim to give both parties the incentives to select due care. Liability laws are based on a concept of ***negligence.*** At a very basic level a party is negligent when it takes less than due care, where due care is defined as that level of care consistent with minimizing total societal costs. A negligent party is open to be sued to pay *damages* for the *harm* incurred by the other party.

In the United States there are two sets of legal rules used in liability cases. In federal *cases* and most *states the rule* is that of *comparative negligence. In* Massachusetts, Virginia, North Carolina and the District of Columbia an older rule of *negligence with a defense of contributory negligence* is used. In economic theory, both rules will remove market failure and lead to optimal conduct by all parties (Shavell, 1987).

The practical application of these liability rules will be illustrated using the two examples from earlier in this chapter. In example I, social costs are minimized when both parties take care. Even if both parties take care, there is still a six-percent probability that an accident will take place. In the event of an accident, the liability rules preclude either party from claiming damages from the other because neither has acted negligently. However, if the railroad takes care but Party A does not, the railroad can seek damages from Party A when an accident occurs because Party A has been negligent while the railroad has not. The railroad can claim from Party A the 100 units of accident cost that it incurs. In these circumstances the railroad will now only bear the five units of care costs. Party A will bear the 100 units of accident damages that it sustains itself plus the 100 units that it has to pay to the railroad. Of course, an accident only occurs 10 percent of the time so Party A can expect to have to bear a combined cost of 20 units of accident damage. The reverse will happen if the railroad is negligent, and A is not.

When both parties have taken due care, or when one party takes due care and the other does not, the comparative negligence and negligence with a defense of contributory negligence rules operate in the same way. The two liability rules differ when both parties have been negligent. Under the rule of negligence with a defense of contributory negligence, each party is barred from recovering any damages from the other because it has itself been negligent. Even in situations where one party has been minimally negligent, and the other party grossly negligent the former party cannot claim any damages from the latter.

Dissatisfaction with the bar that contributory negligence had on the collection of any damages led to the adoption of a rule of comparative negligence in most jurisdictions. Negligence by a party claiming damages against a negligent other party will reduce any award of damages but not necessarily eliminate it altogether. The reduction in any award will depend on comparing the extent to which both parties deviated from their levels of due care.

The payoffs to both parties in example I under either system of liability are shown in the upper part of table 7.5. Now both parties will, correctly, choose to take care. The railroad prefers to take care irrespective of the actions of Party A because it prefers -5 to -16, and -11 to -24. Likewise Party A will always choose to take care because it prefers -5 to -16 and -11 to -20.

In example II, society's preferred outcome is for the railroad not to take care, and Party B to take care. The railroad can never be found negligent as it is impossible to take less than due care. Party B can never recover any accident damages from the railroad. However, the railroad can recover damages from Party

Table 7.5: Payoff Matrices with Negligence with a Defense of Contributory Negligence or Comparative Negligence

Example I		Railroad: No Care	Railroad: Care
Party A	No Care	(-16,-16)	(-5,-20)
	Care	(-24,-5)	(-11,-11)

Example II		**Railroad: No Care**	**Railroad: Care**
Party B	**No Care**	**(0,-16)**	**(-10,-10)**
	Care	**(-6,-9)**	**(-13,-6)**

B if Party B did not take care. For example in the first and third lines of table 7.2, the railroad can recover its 50 units of accident costs that it incurs from Party B. Given that the probabilities of an accident are 0.16 and 0.10 respectively, the expected liability costs to Party B are eight in line one and five in line three. The resulting payoff matrix is shown in the lower part of table 7.5. The railroad, correctly, prefers not to take care because it prefers 0 to -6 and -10 to -13. Party B will correctly choose to take care because it prefers -9 to -16 and -6 to -10.

The examples are very simplified in that the parties can only choose between care and not taking care. In the real world there are gradations of care. Nevertheless, it will still be theoretically true that both liability rules will remove market failure (Shavell, 1987).

LEGAL PROCEDURES

The preceding section presented a theoretical discussion of liability law. In practice, things are less clear-cut and there is the possibility that the law may fail to correct market failure. As a prelude to a discussion of legal failures, it is useful to briefly review legal procedures and introduce some legal terminology.

The branch of law that deals with compensation in connection with bilateral accidents is called ***torts.*** Torts ***are legal*** actions taken by a ***plaintiff*** who has suffered harm to recover ***damages*** from a ***defendant***. ***In*** some cases both parties have suffered harm and both feel that the other party has been negligent. In these circumstances, both parties will take legal action against the other *in* a ***countersuit*** or ***cross-suit.***

The basis for tort law in the United States is the American Law Institute's 1965 ***Restatement*** (Second) ***of Torts,*** which follows from the first Restatement issued in the 1930s. One can regard the ***Restatement*** as a recommendation for "best" law practice, and a summary of what the law is in the majority of jurisdictions in the United States. But it should ***be recognized*** **that** ***the Restatement will be*** secondary to local statutes and cases in an actual trial.

The vast majority of torts are settled privately between the two parties, many without the intervention of a lawyer. Only a small minority of cases goes to trial, and many of the cases are heard without a jury so as to speed settlement. If a trial is **necessary,** the plaintiff issues a ***complaint*** which is "a short and plain statement of the claim showing the pleader is entitled to relief." Witnesses may be introduced by both parties to contest whether the defendant did in fact cause the harm, and the extent of ***the damages caused. The burden of proof*** is on the plaintiff.

The court needs to resolve two things. The first is the due care to expect from a defendant. ***This*** is referred ***to as*** a ***standard of law*** because it is broadly and vaguely defined in legal statues, and will be discussed in the following section. Judges, in a jury trial, specify in their instructions to the jury the legal standard of care. However, the jury has to interpret what that standard implies for the actions expected of the defendant. The second issue to be resolved is how the actual conduct of the defendant compares with the expected level of due care. This is a ***question of fact*** and is decided by the jury based on the evidence presented.

If the court finds for the plaintiff, it also decides on the level of damages to be paid. If the court finds for the defendant, the claim is dismissed. Courts can also decide to award damages ***in excess*** of ***the harm caused,*** called ***punitive damages,*** to penalize a defendant and to act as a warning to deter others from the same conduct. However, the award of punitive damages requires more than just negligence on the part of the defendant. The defendant must have engaged in "willful or wanton conduct."

Few tort cases are appealed because it is only possible to appeal on the basis that the trial judge made errors in decisions about the law or in the conduct of the trial. One cannot appeal based on the "facts" of the case. Appeals initially go to ***an appellate*** court. The appellate court bases its decision on a printed transcript of relevant parts of the trial, supplemented by oral argument by the lawyers involved. Appellate courts usually make written opinions explaining their findings, and their understanding of applicable law. Written opinions on appeals become part of society's case law. At best a person who appeals obtains a new trial.

LEGAL DEFINITION OF ***DUE CARE***

Earlier in this chapter due care was defined in economic terms as conduct consistent with minimization of total societal costs. The legal definition of due care is the care exercised by a "reasonable man under like circumstances." On the face of it, the economic and legal definitions should be equivalent to each other if a reasonable person is assumed to balance the costs of taking care with the resultant changes in expected harm to both himself and other parties.

There is a history of distinguished lawyers who have used economic reasoning to define due care. In a landmark appellate court case, *United States v. Carroll Towing Co. (159 F.2d 169 (2d Cir. 1947))*, Judge Learned Hand used a cost-benefit calculation to determine the level of due care to be taken by the plaintiff who was appealing against a decision of a lower court for the defendant. The case involved the question of whether the federal government who owned a barge that had broken loose from its moorings while being moved by Carroll should have arranged for their own bargee to be in attendance twenty-four hours a day to prevent such a happening. Judge Hand said the plaintiff should have traded off the burden of adequate precautions (i.e., the costs of taking care) against the probability of an accident multiplied by the damages to all parties likely in an accident. Denoting these three factors as B, P and L respectively, he devised a rule that is the level of due care is where $B = PL$.

However, it should be emphasized that the standard of law is very general and stated in the human, if somewhat sexist, terms of the "reasonable man." A purely computational "proof" of due care may not carry the day in court. The jury has wide latitude in interpreting how a reasonable man would have acted and the comparison with the actions of the defendant. The tort textbook by Henderson, Pearson and Silicano (1994) comments that "[i]t is only a slight exaggeration to assert that negligence in most cases is whatever the jury says it is." In many tort cases the major controversy does not center of the actual actions of the defendant, because the "facts" can easily be elicited, but rather on the level of care and conduct that should be expected of the defendant.

The defendant can claim that the plaintiff had also been negligent. The standard of care required of the plaintiff is similar to that required of the defendant. The ***Restatement*** section 463 defines negligence as "conduct on the part of the plaintiff which falls below the standard to which he should conform for his own protection, and which is a legally contributing cause co-operating with the negligence of the defendant in bringing about the plaintiff's harm." Section 464 sets that standard as that of "a reasonable man under like circumstances," although some courts take the plaintiffs mental and physical abilities into account in setting a standard.

FAILURES IN THE LEGAL SYSTEM

If the liability laws work as they should, both parties to bilateral accidents will be given the correct incentives to take the level of care that minimizes total societal cost. However, there are possible failures in the legal system that may lead to incorrect incentives.

The first possible failure is that the potential plaintiff is unable to claim damages ***because*** some ***types*** of harm are ***not legally recoverable.*** Plaintiffs have always been able to recover ***compensatory damages*** for: destruction of personal property, medical expenses incurred, lost earnings and impairment of **earning** capacity, and the loss of the consortium of a spouse or minor child. However, purely economic losses such as increased business expenses or lost revenue cannot be recovered in all jurisdictions. If plaintiffs are unable to recover certain types of harm then there will be less than optimal incentive for the defendant to take care.

A second possible failure occurs when the complaint is served on the ***wrong defendant.*** The most appropriate defendant is a party who has the economic and practical power to influence the level of care and hence the probability of an accident. In practice the defendant may be a party who acts as the agent for the decision maker and has no real say in the level of care taken. For example, chapter 8 will describe how in the case of grade-crossing collisions the railroad is the defendant as the owner of the train that is involved in a collision with a road vehicle, yet the decision of the type of warning devices to install at particular crossings is made by the highway authority.

The third, and probably the most important, possible failure is where the court makes an erroneous ***decision on the level of due care*** that should be taken by either the defendant or the plaintiff. Railroads frequently claim that "anti-corporate" feeling leads juries to hold railroads to a higher level of due care than would be warranted by economic calculations of the type advocated by Judge Learned Hand.

There is a distinct possibility that plaintiffs may be held to a lower standard of due care than is consistent with **minimizing** social costs. A careful reading of section 463 of the ***Restatement*** suggests that plaintiffs have to weigh the cost of taking care against the possible harm they might suffer. There would appear to be a limited duty to consider the harm that their carelessness imposes on the defendant. An extreme example would be where a negligent grade-crossing user collides with a train causing a derailment that damages the locomotive and track and results in a release of hazardous materials. Should the road user have foreseen the wider consequences in deciding on the level of care to take when crossing the tracks?

For example, consider what would happen in example I if the court only considers Party A's cost of taking care and expected harm received in deciding on the level of due care for Party A. This will be equivalent to the private choice made by Party A in table 7.3. The court would say that due care for Party A is not to take care, irrespective of the actions of the railroad. Party A would therefore be held to a lower level of due care than is optimal. The most obvious solution to the possibility for this legal failure would be for the railroad to issue a countersuit against Party A for the damages caused to railroad property. This would make the court aware of the accident damages that the railroad has sustained.

The fourth possible failure ***occurs*** if ***excessive or insufficient damages are*** awarded. The awarding of damages is a controversial topic. This is particularly the case with damages for non-pecuniary harm such as pain and suffering. The concern that some awards are excessive has prompted some states to limit the dollar damages that can be recovered for pain and suffering. Clearly, if the level of damages awarded is inconsistent with the harm caused then the wrong economic signals will be made to defendants. If damages are "too small" then defendants may take less-than-optimal care, and if damages are "too large" then the defendant may exercise too much care.

The **fifth** possible failure occurs when a party is unable ***to pay damages.*** If a defendant is unable to pay for the harm caused to another party, and does not carry insurance coverage to protect against a claim, then the defendant may be motivated to take less-than-optimal care. In practice this is not really a problem when the railroad is a defendant because a typical grade crossing, trespasser or occupational injury claim is for a small amount relative to the assets of the railroad. Most large railroads self-insure against such claims, and smaller railroads can and do obtain insurance coverage. The problem is most likely to emerge when the railroad files a countersuit. Consider the extreme example of the negligent grade-crossing user who collides with a train causing a derailment that damages the locomotive and track and results in a release of hazardous materials. Even if the railroad was successful in its suit, it is unlikely that it would be able to collect full damages.

The sixth and ***final*** possible legal failure concerns ***the transactions costs*** involved in the legal process. These are the costs incurred by plaintiffs and defendants in hiring legal counsel, and the time taken by the parties themselves in preparing their cases. There are also costs borne by the public in providing the judicial system. Transaction costs are an unproductive burden on society and can deter plaintiffs from filing some ***bona fide*** smaller torts.

HUMAN FAILURES

The existence of well-functioning liability process does not eliminate the concern about bilateral accidents. After all, more than ninety percent of railroad fatalities and the vast majority of injuries occur in bilateral accidents. The sad fact is that even with the correct economic incentives, many parties to bilateral accidents take much less care than they should.

Mostly the fault lies with the non-railroad party, especially in the cases of trespassers and highway users at grade crossings. Barring legal failures, these parties must either be ignorant of the tradeoffs between the level of care taken and the probability and consequences of an accident, or do not act in accordance with known economic incentives.

It is easily conceivable that many people are not fully informed. Trespassing and grade-crossing fatalities do not, in general, receive widespread publicity because they claim very few victims at a time. There seems to be a general underestimation by many people of the destructive force exerted by a heavy railroad locomotive and the distance required for a train to brake to a halt.

There is certainly evidence that people may not be thinking clearly when they trespass on the railroad or undertake risky behavior at grade crossings. A third of the grade-crossing victims and at least two-thirds of the trespasser fatalities had been drinking prior to the accident.

It is a matter of semantics as to whether these problems should be described as "market failures." Whatever one chooses to call them, problems of realizing and

Table 7.6: Example III

Level of Care		Cost of Care		Accident Probability	Expected Accident Cost		Total cost
RR	C	RR	C		RR	C	
None	**None**	**0**	**0**	**0.20**	**20**	**20**	**40**
None	Care	0	6	0.12	12	12	30
Care	None	12	0	0.10	10	10	32
Care	Care	12	6	0.08	8	8	34

acting on the correct incentives have market implications. Consider example III shown in table 7.6. In this example both the railroad and Party C would incur damages of 100 if an accident occurred, and the probability of an accident will vary between 0.2 and 0.08 depending on the level of care undertaken by either or both parties. It costs the railroad twelve units to take care, and it costs Party C six units. Society's total costs are minimized at thirty units when Party C takes care and the railroad does not take care.

Consider what happens when Party C ignores the expected accident costs. Party C only considers the costs of taking care and consequently refuses to take care so as to avoid incurring six units in care costs. What should society do? One option is to undertake a public information campaign to make Party C cognizant of the accident costs it might incur, the probability of such an accident and how preventive actions by Party C might lessen these probabilities. One can see evidence of this approach ***in*** the ***Operation Lifesaver*** campaign undertaken to inform the public about the dangers of grade crossings, and the presentations made by railroad employees in schools to inform students about the dangers of trespassing.

But what if Party C still will not respond to the information, or is under the influence of drugs or alcohol? If Party C refuses to take care, society only has the choice between lines one and three. In these circumstances it will be desirable to make the railroad take care so as minimize social costs at thirty-two. Society may have to compensate for the inappropriate actions of one party by requiring the other party to take more care than it otherwise would, a so-called ***second-best solution.*** For example, the government may require railroads to install active warning devices at grade crossings, or erect fencing along the right of way, so as to protect against persistently-negligent highway users and trespassers.

8 HIGHWAY GRADE CROSSINGS

Collisions between highway vehicles and trains are very costly. Calculations later in the chapter will suggest that a typical grade-crossing collision causes **$450,000** of harm. The physics of a heavy railroad locomotive versus an automobile means that highway users suffer more than ninety-five percent of the harm. The probability of a collision can be affected by the actions taken by both the highway user and the "railroad." The highway user affects the probability by their conduct in checking whether a train is approaching before using a crossing. The "railroad" affects the probability by deciding on the type of warning signs and devices that are installed at individual crossings.

To describe the party that decides on the provision of warning devices as the "railroad" is somewhat misleading. The railroad does not act alone in the provision of grade-crossing warning devices. This responsibility is shared between the railroads, municipalities, state highway authorities and the federal government. The latter provide ninety percent of the costs of providing upgraded warning devices under the 1974 Rail-Highway Crossing Program.

SOCIALLY OPTIMAL LEVELS OF CARE

The starting point for the analysis is the determination of the socially optimal levels of due care for the "railroad" (RR) and the highway user **(HU).** For expositional simplicity the shorthand term "railroad" will be used to represent the whole cast of characters involved in the decision to provide warning devices. Of necessity the analysis will be very simple, and make some very broad and sweeping assumptions about collision probabilities, prevention costs, and the harm caused by collisions.

Both the railroad and the highway user can choose between two levels of care. The railroad can choose between providing passive warning devices, such as crossbucks or stop signs, or a higher level of care involving active warning devices such as train-activated flashing lights or gates. Highway users can either adopt their ***current*** level of care, or take a ***higher*** level of care. Currently highway users are not as careful as they could be. Railroad lawyers comment that they rarely encounter a grade-crossing case in which the highway user has not been negligent in some way, either by reckless behavior or by inattention. A higher level of care will be defined as that necessary to reduce the number of collisions to only those where the highway user has inadvertently stalled on the crossing. Adopting this higher level of care would reduce the number of collisions by threequarters at crossings with passive warning devices, and by eighty percent at crossings with active warning devices (FRA, 1997b).

The first step is to estimate collision probabilities. Based on information on crossing usage in FRA (1997b), one can calculate that at crossings with passive warning devices and with highway users exercising their current level of care, the probability of a collision is 63.5 per billion vehicle crossings. Installing flashing lights at such crossing is estimated by the DOT to reduce collisions by seventy percent to 19.1 per billion vehicle crossings (DOT, 1986). Based on the discussion in the previous paragraph, these two rates would be reduced by seventy-five percent and eighty percent respectively if highway users exercised a higher level of care.

The second step involves an estimation of the costs both parties incur by taking care. Industry sources suggest that the cost of installing flashing lights at a crossing is about $80,000. For simplicity, the initial installation costs will be amortized equally over the twenty-year life of the equipment. There are annual maintenance costs of $1,700, calculated based on inflating figures given in DOT (1986) by a construction price index. Therefore, the cost of care is $15.60 a day.

The cost to the highway user of taking a higher level care is more speculative. When passive warning devices are installed, drivers may have to slow down to observe if a train is coming. The word "may" is used because circumstances will vary from crossing to crossing. At some crossings in prairie states, drivers are able to observe a train approaching from a great distance away and do not need to slow down. At other crossings, curvatures of the highway or the railroad require vehicles to slow down on all occasions. Other crossings will be somewhere in between where vehicles only need to slow down at certain times of day or in certain climatic conditions. The proportion of traffic that needs to slow at a particular crossing in order for road users to take a higher level of care will be denoted by P.

The model assumes that currently nobody slows down, which is clearly an exaggeration. If a driver has to slow down in order to observe whether a train is approaching, the model assumes that the driver will brake from fifty miles per hour to twenty miles per hour when he or she encounters a crossbucks sign at 750 feet from a crossing. This slowing and the subsequent acceleration cause a time penalty of ten seconds. Transportation economists have a long history of estimating dollar valuation of time delays. More recently, researchers have shown that the valuation of time depends on the circumstances in which the time delay occurs. The time taken while driving on a congested highway has been found to be valued higher than the time taken while driving on an uncongested highway (Bein, Miller and Waters, 1994). Certainly time taken slowing for a railroad crossing or waiting at the crossing is as irritating as driving in heavy traffic. This research suggests the value of time in such circumstances is about $13 an hour, which would translate into a timedelay cost of 3.6¢ for each driver who slows down. Therefore if highway users adopt a higher level of care, they would each incur a cost of 3.6P¢, where P is as defined in the previous paragraph.

Table 8.1: Economic Model of a Highway Grade Crossing

Level of Care		Cost of Care (¢)		Collision Probability	Expected Collision cost (¢)		Total Cost
RR	HU	RR	HU		RR	HU	
Passive	Current	0	0	6.35×10^{-8}	0.08T	3.00T	3.08T
Passive	Higher	0	3.6PT	1.59×10^{-8}	0.02T	0.75T	0.77T+3.6PT
Active	Current	1560	0	1.91×10^{-8}	0.02T	0.72T	0.75T+1560
Active	Higher	1560	≈ 0	3.81×10^{-9}	0.01T	0.14T	0.14T+1560

T = annual average daily highway traffic, P = proportion of traffic required to slow down

If flashing lights are installed, taking a higher level of care requires some highway users, who previously cut across at the last moment, to incur a delay of three minutes while they wait for the train to pass. At least 1530 in every million highway users will incur this delay. This is the number of collisions that are avoided when the highway users take a higher level of care. For every one highway user that ignores flashing lights and gets struck by a train, there are probably nine others **who** ignore the lights but do not get struck. Even accounting for the ratio of "successful" to "unsuccessful" attempts to "beat the train," the ***average*** cost of taking care is negligible.

The final step is to estimate the harm caused by a collision. Each collision at a crossing with passive warning devices results in 0.12 highway user fatalities, 0.44 highway user injuries **(FRA, 1997b),** and $4,000 damage to the highway vehicle. In addition the railroad bears the cost of 0.0003 fatalities and 0.03 injuries to its employees and passengers, and $6,000 in damage to its property **(FRA,** 1997b). Recent research has estimated the social cost of a fatality at $3.15 million, and that of an injury at $225,000 at current prices (Miller et al, 1991). Each collision at a crossing with passive warning devices will therefore be expected to impose harms of $470,000 on the highway user, and $13,000 on the railroad. There will also be delays to railroad and highway traffic which are not quantified.

When active warning devices are installed, the severity of any resulting collisions changes to 0.1 highway user fatalities and 0.36 highway user injuries. Assuming that the consequences of a collision in terms of property damage or casualties to railroad employees and passengers remain unchanged, a collision at a crossing with active warning devices will impose harms of $380,000 on the highway user, and $13,000 on the railroad.

Table 8.1 brings together the information discussed above in a format similar to the analysis of chapter 7. The table represents the total costs and benefits per day for an individual crossing, with monetary amounts expressed in cents. The total costs of care and the expected number of collisions depend on the annual average ***daily*** highway traffic using ***the*** crossing. ***Ceteris paribus*, *the*** greater the highway traffic, the greater will be the number of people who have to take care, and the greater the expected number of collisions. The amount of traffic is denoted by **"T."**

Society's ultimate goal is to encourage that combination of care that minimizes total social cost in the final column of table 8.1. The lowest-cost combination will depend on the values taken by P and T. Table 8.2 shows the levels of due care that should be taken by the railroad and the highway user for different values of the levels of daily traffic, and the proportion of times that the highway user would have to slow down to exercise a higher level of care.

The current level of care taken by road users can only be condoned at crossings which are used by less than 550 vehicles a day and which require more than **two-**thirds of the traffic to slow down to properly observe for a train. If the careful highway user had to slow every time they used these crossing, it would actually be in society's interest to encourage the motorist to **speed** across the railroad without checking because the time delays are more costly than the resultant reductions in

Table 8.2: Due Care by Crossing Characteristics

%	Average Annual Daily Highway Traffic						
0.00	250	500	750	1000	1500	2000	3000
0.25	0.25 0.00 Passive / Higher						
0.50							
0.75	Passive /		Active / Higher				
1.00	Current						

collision costs! In all other circumstances, society would wish that highway users exercise more care.

The decision whether to install active warning devices depends on the level of highway traffic. At crossings where sight lines are so limited that all prudent highway users would have to slow down, active warning devices are justified when daily traffic exceeds 550 vehicles a day. At the other extreme, where visibility is good that no prudent motorist is required to slow down, active warning devices should only be provided when daily traffic exceeds 2,600.

Even though they are based on some sweeping generalizations, these calculations are probably not too far away from the mark. Only twenty-four percent of public crossings with less than one thousand vehicles a day have active warning devices, whereas seventy-four percent of crossings with more than one thousand vehicles a day have such warning devices (FRA, 1997b).

Nevertheless there is evidence to suggest an insufficient deployment of active warning devices. Currently 3,000 of the 18,800 crossings with more than five thousand vehicles using them each day are not fitted with active warning devices. A third (11,000) of the 34,500 crossings which carry between one thousand and five thousand daily highway vehicles lack active warning devices. The model suggests that all of the former and, perhaps, half of the latter crossings should receive upgrades. Consequently, about 8,500 grade crossings need upgrading.

In summary, the main conclusions that can be drawn from the model are twofold. Firstly, in most circumstances highway users should take more care that they currently do. Secondly, there is an insufficient deployment of active warning devices. The remainder of this chapter discusses why these problems have arisen and what policy initiatives can be taken to ameliorate the problems.

INSUFFICIENT HIGHWAY USER CARE

Highway users should have very strong incentives to take care when crossing the railroad. The highway user in a grade-crossing collision has a one in seven chance of being killed and a one in two chance of sustaining a major injury. Nevertheless some proportion of highway users take far less care than they should. There would appear to be a number of reasons why this is so.

The first is that highway users do not fully appreciate the dangers posed by grade crossings, and exaggerate their own abilities to extricate themselves from a close call. The second is that the standard of conduct required at crossings with passive warning devices is not clearly defined. The third is that the legal system may distort the economic incentives by displaying an anti-railroad bias.

Poor Appreciation of the Dangers

With the exception of few well-publicized cases, most grade crossing collisions are not widely reported. This will tend to make people bias downwards their perceived probability that a collision will occur. Also, most highway users also feel that their own skill and diligence can avert a possible collision which reduces their fear of this risk. In studies, most auto drivers rate their driving skills "above average."

There is also a "it will not happen to me" effect. Research by psychologists suggests that most people feel that they are less likely to be affected by a particular hazard than the "average" person (Slovic et al., 1980). In addition repeated encounters with a hazard without any untoward personal experiences has been found to reinforce that opinion (Slovic et al., 1978). Even the most careless grade-crossing user is likely to go decades without having a close encounter with a train.

Of course, the vast majority of highway users do exercise due care when encountering a grade crossing. There is just a small minority of drivers who indulge in risky behavior not only at grade crossings but also in other aspects of their driving. Sometimes this is due to ignorance of the risk, but more often it is because their senses have been dulled by alcohol or drugs. A NHTSA study (1994) found that a third of the grade-crossing victims had been drinking prior to the collision, and a quarter had a blood-alcohol content higher than the legal limit.

Poor Definition of Appropriate Conduct

When active warning devices are installed, most road users are well aware of prudent conduct. The law is quite clear that drivers must always stop when the lights start to flash and/or the gates are lowered. Society has made it quite clear that it is inappropriate to enter the crossing after the lights start flashing or to weave around lowered gates. Usually railroads can successfully defend themselves against suits when active warning devices are installed. Witnesses, such as motorists who are waiting at the crossing, can bring evidence that the highway user ignored the flashing lights or drove around the gates.

This is not true when passive warning devices are installed. The ambivalence about the standard of conduct expected has already been demonstrated in this chapter. At little-used crossings with poor sight lines, society would actually condone highway users who speed across the crossing rather than slowing down and reconnoitering.

The State of Illinois ***Rules of the Road*** book advises drivers approaching crossings with passive warning devices to "slow down, look and stop if **necessary.** Roll your vehicle windows down and listen to make certain other noises do not block out the sound of a train. If a train is approaching, ***stop and wait.*** Do not try to race the train to the crossing." Note that the advice indicates that the stopping and looking are only required "if necessary." Yet, later in the booklet drivers are given a stronger caution in that they must be "especially careful! Drive as though you ***expect a train*** on any track at any time" (emphasis in the original).

The ambiguity concerning exactly how a highway user should act has been debated all the way to the highest court in the land. In 1927 the United States Supreme Court in the case of the ***Baltimore and Ohio R.R. v. Goodman (275 U.S.*** 66, **70 S.** ***Ct 24, 72 L.*** Ed. **167** ***(1927))*** decided that a prudent motorist should always stop and reconnoiter and that this standard of conduct should be written into law. This decision lead to the passing of laws in some states requiring that highway users had to "stop, look and listen."

However seven years later the composition of the Supreme Court had changed, and the Court abandoned efforts to judicially codify standards of due care. In the case of ***Pokora v. Wabash Ry. (292 U.S. 98, 54 S. Ct. 580, 78 L. Ed I149 (1934))*** the Court overturned the specific conduct implied in the 1927 decision, and commented that **"[s]tandards** of prudent conduct are declared at times by courts, but they are taken over by the facts of life. To get out of a vehicle and reconnoiter is an uncommon precaution, as everyday experience informs us." The Court noted that the decision in the earlier case had caused confusion in federal courts, and had received "wavering support" in state courts.

One would therefore conclude that the onus is very much on the individual highway user to decide on the most prudent action to take at a particular crossing. The law provides no specific guidance. Juries have to use their discretion in deciding whether the specific conduct of the highway user accords with that of the "reasonable man" when considering contributory negligence in a case brought against the railroad.

Legal Bias Against the Railroad

It is difficult to draw definitive inferences on biases in the legal system. More than ninety percent of cases are settled out of court, and there is no public data on the negotiation of settlements. In jury trials under the comparative negligence rule, the jury does not have to explicitly specify how negligent they feel the highway user has been, they just implicitly reduce the amount of the award of damages to the highway user to reflect the perceived negligence.

Railroad lawyers express the concern that courts have held highway users to a lower standard of care than is appropriate. Evidence that the highway driver had ignored a flashing light, drove around the lower gates, was exceeding the posted speed limit, was driving under the influence of alcohol or drugs, or drove into the side of the train is usually successful in indicating contributory negligence.

However, it is difficult to prove or disprove whether the highway user had properly “looked and listened” at crossings equipped with crossbucks signs. In these situations the law neither requires the highway user to come to a stop, nor specifies an appropriate speed that the highway user must slow down to. Therefore, plaintiffs’ attorneys are successful in arguing that their client had taken due care. When the collision occurs at a little-used rural crossing, there are usually no independent witnesses to attest to the actions of the plaintiff. Railroad lawyers feel that anti-corporate bias by some juries gives the “benefit of the doubt” to the highway user.

Railroads feel particularly aggrieved when the highway casualty is a passenger in a road vehicle. Passengers cannot by law be held to be contributorily negligent to the collision. Therefore if an automobile passenger issues a complaint against the railroad, the railroad cannot make any defense to reduce the claim. One strategy by the railroad is to issue a counter-suit against the driver of the highway vehicle to protect against judgements in favor of the automobile passenger. But because the railroad has more financial resources than the driver of the highway vehicle, it is frequently saddled with bearing the difference between the cost of the passenger’s claim and whatever monies can be obtained from the insurance held by the automobile driver. Therefore, negligent drivers of multiple-occupant vehicles may not face the full costs of their actions.

There is no doubt in my mind that highway users are frequently held to a lower standard of due care than they should be, particularly for cases involving crossings with passive warning devices. But does this legal failure account for the lack of due care exhibited by some road users? I think not. Even though the legal system may be biased in favor of the highway user, most of the harm from a collision falls on the highway user and rational drivers should realize that it is in their own self interest to exercise more care at grade crossings.

ENCOURAGING MORE HIGHWAY USER CARE

There would appear to be three possible policy options available to respond to the insufficient care exercised by highway users. The first is to try to make highway users aware of the dangers posed by grade crossings. The second is to try to define appropriate conduct at crossings with passive warning devices. The third is a second-best solution which accepts the fact that some highway users will be negligent and compensates by installing active warning devices at many crossings.

Informing the Public

In recent times, federal and state governments and the railroads have been actively promoting *operation Lifesaver,* a public relations campaign that highlights the dangers of grade crossings, and appropriate conduct when using a crossing. This worthwhile campaign coupled with the installation of active warning devices at many crossings has been credited with the substantial reduction in grade-crossing fatalities since 1974.

Defii Conduct at Crossings with Passive Warning Devices

A second option which appears to be gaining some popularity is to try to resurrect "stop, look and listen" requirements by replacing crossbucks signs by stop signs. Currently about seven percent of crossings are fitted with stop signs, an increase from two percent twodecades ago. Railroad lawyers are typically in favor of this movement because it allows the railroad to introduce evidence that the highway user did not come to a full stop as a way to demonstrate contributory negligence.

To my mind this is a very worrying trend. For crossings with a lot of road traffic and little rail traffic, it is likely that any cost-benefit analysis would show that the delays caused to road traffic by decelerating, stopping and accelerating would outweigh any reductions in collisions. Making road users come to a halt when, for the most part, no train is likely to be approaching might encourage contempt for stop signs and encourage road users to ignore stop signs elsewhere on the highway network. I also suspect that there is a real possibility that the deployment of stop signs may lead to an increase in rear-end collisions between automobiles. There is also the consideration that a highway vehicle moving at speed is on the crossing for a shorter period that a vehicle that is accelerating from a stop which would tend to reduce the probability of collision.

A Second-Best Approach

The final option is to just accept that some highway users are incapable of displaying appropriate care at crossings, especially those with passive warning devices. In effect society would accept that the second and fourth lines of table 8.1 will not occur in practice. Left with the choice between lines one and three, society would choose to install active warning devices when $0.75T + 1560$ is less than $3.08T$. Active warning devices will be justified at all crossings carrying more than *670* highway vehicles a day. This criterion would add another 11,500 to the list of 8,500 public crossings that were recommended earlier in the chapter for upgrading to active warning devices (FRA, 1997b).

INSUFFICIENT DEPLOYMENT OF ACTIVE WARNING DEVICES

The total number of public crossings that should be upgraded to active warning devices depends crucially on whether one feels that it is possible to educate drivers to exercise proper care at crossings with passive warning devices. If behavior can be improved there may be as few as 8,500, if not there may be as many as 20,000. In other words somewhere between five and twelve percent of public crossings still need to be upgraded to active warning devices. While this may sound like a large number of crossings, it needs to be put in the context of the large strides that have been made in the past quarter century.

Table 8.3 shows the distribution of warning devices at public crossings in 1978, the first year for which data are available, and 1996. Two things are immediately apparent. The first is that track abandonment and crossing consolidation have led to the disappearance of a quarter of the public crossings in two decades. The second is that there have been upgrades of all types: crossings that previously had no signs now have passive warning devices, crossings that used to have passive warning devices have been fitted with flashing lights, and gates have been installed at crossings that used to have only flashing lights. However, it is apparent there has been an emphasis on installing gates.

The big impetus for these changes has been the Rail-Highway Crossing Program of 1974, commonly referred to as the ***Section 130 Program.*** The federal government has spent almost $6 billion, at current prices, to improve grade

Table 8.3: Distribution of Warning Devices at Public Crossings

	1978			1996		
	Number	**%**	**%**	**Number**	**%**	**%**
Gates and Lights	13,959	6	27	30,813	19	40
Lights Only	44,959	21		34,854	21	
Crossbucks Signs	138,472	64	66	79,376	49	56
Stop Signs	3,525	2		10,832	7	
Other Signs	1,054	0		501	0	
No Signs	14,636	7	7	6,050	4	4
Total	216,611			162,426		

Sources: FRA (1979, 1997b)

crossings. Typically federal money pays for ninety percent of the cost of improvements. The remaining ten percent comes from the railroad, the state highway authority, the municipality, or a combination of all three. Currently the annual federal appropriation is $155 billion.

On the face of it, the combined federal and local funds of approximately $172 million a year could pay for installing flashing lights at all crossings that deserve them in a five to ten-year period, at a cost of $80,000 per crossing. The reality, of course, is that Section 130 funds are spent on other types of upgrades as well: adding gates, improving highway alignments, renewing existing warning devices, and closing little-used crossings and consolidating traffic onto neighboring crossings. Therefore, in recent times only about 500 crossings a year have been upgraded from passive to active warning devices. At this rate of progress, a realistic prediction of when all deserving crossings will be upgraded is somewhere between the years 2013 and 2036.

One might argue that the year 2036 is a long way away, and at that time the Section 130 Program will have been in existence for more than sixty years! One could clearly argue that Section 130 funding is currently insufficient, and that increased public expenditures would be justified on the basis of a cost-benefit analysis.

LEGAL IMPEDIMENTS TO THE DEPLOYMENT OF APPROPRIATE WARNING DEVICES

Some observers claim that the grade-crossing program has been hampered by a legal problem which places the railroad and not the highway authority as the defendant in suits brought by injured road users. The railroad has always had a common law duty to maintain safe crossings, including a duty to select and install appropriate warning systems at hazardous crossings. Prior to the 1970s the railroads were the appropriate legally responsible party as they determined the type of warning device to install at a particular crossing, and bore the costs of installation and maintenance.

The worsening financial condition of the railroads in the 1960s coupled with the rise in automobile traffic prompted the ICC and the DOT to recommend that the financial burden and the planning of crossing improvements should be transferred to the highway authorities. The ICC argued that the change would be equitable because "[h]ighway users are the principal recipients of the benefits" (ICC, 1962). The DOT concluded that it was anomalous that railroad grade crossings were "the only place along the highway where the state authorities do not have total control over the installation. . . of traffic control devices" (DOT, 1972).

Consequently the Section 130 Program was established, and uniform national standards were developed to determine the need for, and provide for the installation of, warning devices. These were manifested in the addition of a chapter on "Traffic Control Systems for Railroad-Highway Crossings" to the FHWA's *Manual on Uniform Traffic Control Devices* (FHWA, 1988). A cost-benefit manual (DOT, 1986), an associated handbook (FHWA, 1986), and computer software were developed to permit highway authorities to set priorities so as to allocate their budgets toward the most needy crossings.

This fundamental change in the decision making was not balanced by a change in the courts. In nearly all grade-crossing cases the railroad is usually the sole defendant. This leads to two problems. The first problem is that state highway authorities who now make the decisions on the deployment of warning devices are not given the economic incentives to press for larger state and federal budgets to speed the installation of active warning devices. The second problem is that the priority order in which crossings are treated can be distorted by railroads who react to random collisions by pressing for installation of active warning devices at little-used crossings so as to avoid liability in the event that another collision occurs.

The first problem arises because the highway authority does not bear any financial repercussions from failing to upgrade deserving crossings. For example, if a road user involved in a collision at a crossing equipped with passive warning devices issues a tort arguing that "someone" was negligent in not installing flashing lights, that tort can only be served on the railroad. The state highway authority suffers no penalty for failing to act, and thereby has little incentive to press both its state legislature and the federal Congress for increased funding of the grade-crossing program.

The second problem requires more explanation. If a collision occurs at a crossing with passive warning devices, courts frequently look to the past history of the crossing when determining negligence. If another collision had occurred in recent memory, this can be used as evidence that the railroad had been negligent in failing to respond to the earlier collision by installing an active warning device. Moreover, the court may decide that the inaction of the railroad requires awarding punitive damages.

To avoid such judgments, railroads may press the highway authority for installation of active warning devices at any crossing where a collision occurs. The railroad may persuade the highway authority to do this by offering to pay the full ten-percent match funds, or even more, required to obtain federal Section 130 funding. Clearly this would not be a problem if that crossing deserved to receive active warning devices anyway, based on the objective rules described earlier in the chapter. However, collisions do occur at little-used crossings that may not deserve upgrades, and the installation of warning devices at these crossings would be a misallocation of resources.

An example will illustrate the problem. A railroad has 150 grade crossings fitted with passive warning devices. Fifty of these crossings are heavily used and carry 5,000 highway vehicles a day. The other 100 are less busy and only carry 1,000 vehicles a day. Assume that the objective standards developed earlier in the chapter indicate that all of the busier crossings should be equipped with active warning devices, but the less-busy ones should not. Based on a probability of a collision of 63.5 per billion highway-vehicles crossings, the Poisson distribution that is commonly used to explain collision occurrence predicts that twenty-one of the less-busy and thirty-four of the busier crossings will experience a collision over a ten-year period.

The railroad will push to have active warning devices installed at all of these fifty-five crossings because it knows that a second collision will occur at two of the less-busy and sixteen of the busier crossings in the ten-year period. Yet society would be better served if none of the less-busy crossings were fitted with active warning devices, and the money thus saved was used to upgrade all of the busier crossings.

An objective observer might think that this problem could be avoided if, in response to a suit brought after the second collision at a less-busy crossing, the **railroad** called a witness from the Federal Highway Administration or the state highway authority to testify that the level of traffic at the crossing did not merit an active warning device. While railroad lawyers say that this is a reasonable line of defense, it does not always carry the day for the railroad. Judges may rule that this evidence is inadmissible in that the railroad and not the highway authority is the defendant, and it is the railroad's and not the highway authority's conduct that is on trial. Plaintiffs' attorneys can also argue that while the highway authority may not have wanted to install active warning devices, the railroad could have acted independently and installed devices.

A POSSIBLE SOLUTION?

A United States Supreme Court decision in 1993 coupled with a 1995 proposal by the **FRA** provides some hope that the there may be a change in the placing of legal responsibility. The Supreme ***Court case, CSX Transportation Inc. v. Easterwood*** (113 S. Ct. **1732),** involved questions concerning the speed of a train that was in collision with a highway user at a grade crossing. The tram was traveling at less **than** ***the speed*** limits contained ***in the*** track standards ***in the Federal Railroad Safety Act*** of 1970 but more than the speed limit specified in a local ordinance. The court ruled that federal law took precedence because the 1970 Act only allowed state and local governments to issue safety regulations if the FRA had not exercised its **rulemaking** powers in that area.

This ruling has been used to suggest that the use of Section 130 **funds** to provide passive warning signs at a crossing is an indication that the federal government has concluded that active warning devices were not appropriate for that crossing ***(Hester v. CSX Transp., Znc (61 F.3d 382 (5th Cir. 1995)),*** and ***Armijo v. Atchison, Topeka, and Santa Fe Ry. Co (87 F.3d 1188 (10th Cir. 1996))). As*** a result there would be a federal preemption of state common laws which place responsibility on the railroads for selecting appropriate warning devices. The practical implication is that railroads would no longer be held liable for decisions on the appropriate type of warning device installed at a particular crossing.

McFarland (1997) indicates that most cases follow the precedent of ***Easterwood,*** but preemption is still a controversial issue. ***In Shots v. CSX Transp., Znc (38 F.3d*** 304 ***(7th Cir. 1994))*** the plaintiff argued successfully that while the federal government had given the State of Indiana money to install crossbucks signs at

2,638 crossings, it had not investigated the most suitable warning device for the crossing at which the collision occurred.

To solidify the case for preemption, the federal government proposed in 1995 to introduce a rule that would remove the railroad entirely from decisions on installation of warning devices (FRA, 1995c). These decisions would be made solely by state and local highway authorities using uniform national FHWA guidelines. Under the proposed rules the railroads would only be required to provide information on current and forecasted rail traffic and provide technical expertise in the design and maintenance of warning systems. Railroads would not be allowed to initiate installation of warning devices. The FRA stated that it expected the proposed rules would "substantially subsume" the selection and installation of warning devices and as such "preempt state laws covering the same subject matter."

In general one should be favorable to the proposed rule. Decisions on appropriate warning devices are primarily driven by the amount and nature of highway traffic to which only the highway authority is privy. The highway user is the primary beneficiary of reduced collisions. While some people are critical of the algorithms used to decide on the priority list of crossings deserving upgrades, there are clearly longstanding uniformnational methodologies to assist highway authorities in their tasks.

Unfortunately there is a downside. The federal government has sovereign immunity against claims for either things it does or things it fails to do. One cannot bring suit against the federal government. States also have sovereign immunity, although they can choose to waive it. However, even if sovereign immunity is waived, there are often limits on the dollar amounts of claims.

Discussions earlier in this chapter indicated that there are many crossings which deserve upgrades that will not be treated for many years due to budget limitations. Highway users killed or injured at these crossings will either be unable to seek damages or have the amount of damages severely limited despite the fact that they have a *bona fide* complaint.

It is therefore not surprising that the proposed rule was vigorously opposed by plaintiffs' trial attorneys. Critics also feared that the removal of legal recourse for plaintiffs may reduce the pressure on the federal government to continue to support the Section 130 Program at its current level. While the motivation for the 1995 FRA proposal may have been an honest attempt to place decision making with the most appropriate body, the principal effect was to limit corporate liability at the expense of individual highway users. To my mind, a big flaw of the 1995 proposal was that highway authorities cannot be held legally accountable for the conduct of their crossing-improvement programs. A waiver of sovereign immunity should have been included.

The proposed rule was quietly dropped in 1997. Railroad lawyers suspect that it would only be resurrected when the mood of the country again turns toward tort reform and limitations on corporate liability. Of course, the *Easterwood* decision still stands, and courts can interpret the decision as a *de facto* case for preemption.

9 TRESPASSERS

Preliminary data for 1997 suggests that trespassing has become the leading source of death on the railroads. The number of annual trespassing victims is greater than the number of grade-crossing fatalities for the first time in over half a century. Trespassing is primarily a problem in built-up areas, and mostly involves single adult males who are under the influence of alcohol.

SOCIALLY OPTIMAL LEVELS OF CARE

It is difficult to construct a table, similar to those in the previous chapters, to calculate the optimal level of due care to be taken by both the railroad and the trespasser. There are no data on the magnitude of the trespassing problem. Hence it is impossible to calculate probabilities that a trespasser will be injured. It is also difficult to conceive of a notion of how to quantify the costs a potential trespasser would incur in taking care.

However it is possible to tier the standards that society has adopted for the level of due care to be shown by both parties. There is lengthy legal case law on the duties expected of trespassers and holders of land.

Due Care by Trespassers

There is a strong legal presumption that trespassers, and not the owners of land, bear the burden of taking appropriate care. Trespassers bear the entire risk of any ***natural hazards*** (such as quicksand) that they encounter, and can only claim damages if they are injured by ***an artificial hazard*** (i.e., something manmade or mechanical) if the landowner had not used reasonable care to post a "warning." However, courts have held that the mere existence of a railroad track is a sufficient warning of the dangers of trespass. The implication is that the law assumes that the public is well aware of the dangers of trespassing on the railroad.

The presumption that trespassers are fully accountable for their actions has been strengthened in the past ten years by the passage of ***Recreational Use of Land*** laws in many states. These laws were prompted by the increase in trespassing by users of all-terrain motor vehicles and bicycles. Under these laws people who enter onto land for recreational purposes assume all of the risks, even those caused by unmarked artificial hazards. Some, but not all, railroad lawyers feel that consequently the entire burden of taking care is placed on snowmobilers, hunters and fisherman, and perhaps even recreational drinkers, who trespass on the railroad.

A trespasser who is on the land to commit a crime is held to an even higher level of care. The landowner is only required to avoid intentionally injuring the trespasser. Therefore thieves, vandals, and transients who are attempting to ride a freight train without paying, bear the entire burden of taking care.

The only people who are expected to exercise a lower level of care are children who "because of their youth do not discover the condition or realize the risks involved in intermeddling with it or in coming within the area made dangerous by it" ***(Restatement*** Section 339). In general, there is a view that children under the age of six years old cannot be found contributorily negligent. Between the ages of six and twelve there is a presumption against contributory negligence.

Due Care by the Railroads

As can be inferred **from** the previous paragraphs, the level of reasonable care expected from the railroad is quite low. In general, there is no legal requirement that the railroad construct a fence on the edge of its property. In a perverse way the law actually discourages rather than encourages fencing. The railroad is much more liable if it is shown that a fence was provided but then was not maintained, that if a fence did not exist in the first place. There is not a general requirement that the railroad post warning signs, although they generally do so at places of limited clearances such as tunnels or trestles. There is also no duty to secure the doors of empty box cars to deter traveling transients.

A more contentious issue is how the railroad should act when it is aware that trespass takes place repeated at certain locations. A trespasser is defined in section ***329*** of the ***Restatement (Second) of Torts as*** "a person who enters or remains upon land in the possession of another without a privilege to do so created by the possessor's consent or otherwise." Some courts have taken the view that if trespass takes place repeatedly at a certain point, and the possessor of the land has tolerated the trespass, then the trespasser could be regarded as a ***licensee.*** Landowners have to show a higher level of care to a licensee than they do to a trespasser. Section ***342*** of ***the Restatement*** makes the possessor liable if it can be shown that the licensees were not aware of the risks involved, and that the possessor had not taken care to make the conditions safe or warn the licensee of the danger.

In legal proceedings the issue of whether a person is a trespasser or a licensee has traditionally been open to some debate. Therefore some states such as New York and New Jersey have done away with the distinction and hold a landowner to the higher standard when trespass is known. Therefore, there would appear to be a duty to "anticipate future trespass" at locations where trespass occurs regularly, and to react to a "well-worn path" crossing the railroad. In general the posting of signs by the railroad is regarded as sufficient action. Railroads do take further actions such as conducting patrols and working with local authorities and police departments. Where there appears to be a well-used informal foot crossing then the railroad might be expected to provide a regular crossing, a footbridge, or erect fencing to make people use nearby formal crossings.

Railroads have a duty to protect their property against children. This is partly because, **as** explained in the previous section, there is a presumption that young children are not aware of the consequences of their actions. In addition the law recognizes that children may be attracted to playing on the railroad. This is formally known as the ***attractive nuisance doctrine*** and more commonly referred to ***as the turntable doctrine as an*** early case involved a child injured while he was trespassing on a railroad turntable. The ***Restatement requires*** reasonable care to remove the danger or otherwise protect the children, but does recognize the economic trade offs between the "burden of eliminating the danger" compared with the "risk to the children involved." The actual conduct expected of the railroad is somewhat unclear. **In** areas where there may be very young children a fence may be required, whereas for older children presentations in neighboring schools warning of the dangers may be sufficient.

While there is a limited requirement to prevent trespass, the railroad is held to a higher level of care when trespassers are discovered. In most states there is a duty to "avoid injury" in protecting land against trespass and in expelling a trespasser. In a minority of states, a possessor of land only has to refrain from "wanton or willful conduct." The implications are illustrated by the case of ***Hines v. Denver & Rio Grande Western Railroad Co. (829 P.2d 419 (Colo. App 1991))*** where the railroad was found negligent because the tram crew did not use reasonable care in keeping a proper lookout, and did not take appropriate action in applying the brakes and sounding the whistle when their train encountered the husband of the plaintiff walking along the rails in a canyon while on a fishing trip. While courts do expect the engineer to apply the brakes and sound the whistle, railroad lawyers point out the most courts are very sympathetic to the emotional distress that a trespassing death causes a locomotive engineer.

COMPARISONS WITH ACTUAL LEVELS OF CARE

In general, one can conclude that society places few requirements on a landowner to protect against trespass. Indeed railroad lawyers comment that, with the exception of cases involving children, railroads are rarely found by courts to have acted negligently in damage suits brought by trespassers or their relatives. Situations where the railroad might be liable, such as those involving "well-worn paths" or children are in the minority. Less than ten percent of fatally-injured trespassers were crossing the tracks, and a good proportion of these would be at random places rather than in high trespass areas. Less than fifteen percent are young people, and only a small proportion of these are under the age of twelve.

Therefore in at least threequarters of the cases of trespasser fatalities, society has placed the burden of taking precautions entirely on the trespasser. There is considerable evidence that trespassers take considerably less care than they should. A third of the trespassing victims were sitting or lying in the right of way. Alcohol is involved in somewhere between sixty and eighty percent of trespassing cases, and when alcohol is involved the level of consumption is very high. Trespasser fatalities occur disproportionately on summer weekend evenings. It would appear that the railroad right of way is a popular place for poorly-educated single adult males to socialize and drink. Courts have typically held drunks to the same level of care as would be required of a sober person. This is known in legal language as taking ***prior precautions.*** A drunk is not only held to be aware of the dangers of trespassing on the railroad, but also should have exercised due care in deciding whether to become intoxicated.

THE ECONOMICS OF FENCING

At various times Congress has raised the issue of imposing regulations to requiring railroads to erect a fence along sections of their right of way. In Britain and on most urban mass transit lines fencing is very common. In the case of mass transit this is primarily to protect the public against electrocution from the third rail. The publicly-owned Amtrak took a decision to fence its heavily-used North-East Corridor. But in many countries on the continent of Europe, in North America and in most other parts of the world fencing is not common.

Of course, American railroads like other owners of land already fence part of their property to protect against people with a criminal intent to steal or vandalize. They also fence in certain locations to protect against liability to children or to react to high-trespass areas. However, the NTSB (1978a) study indicated that 85 percent of trespasser fatalities occurred at unfenced locations.

Should railroads have a much more general requirement to fence? The argument for fencing is twofold. The first is that a fence discourages young children who do not appreciate the dangers of railroads. The second is that fencing might be seen as a second-best solution if it was felt that it was impossible to educate adults of the dangers of drinking and socializing on the right of way. Although, in a perverse way the existence of a fence can encourage trespass because it makes the right of way an even more private and desirable place for people to socialize, drink, have sex or sleep.

The desirability of fencing can be investigated using a cost-benefit analysis. There are good data on the costs of fencing. Trespassing is primarily an urban problem. Internal calculations by the AAR in 1987 suggested that approximately 10,000 miles of right of way pass through areas with population densities of greater than 800 persons per square mile. If all of these lines were fenced, the cost at approximately $300,000 per mile at current prices would be about $3 billion. Obviously some of this mileage is already fenced, but fencing does get destroyed and deteriorate and requires replacement. Assuming a ten-year life, an ongoing annual expenditure of about $300 million would be required to fence the urban railroad.

The effect of fencing on the number of trespasser fatalities is unclear. In chapter 4, it was shown that the annual rate of trespasser fatalities per head of

Table 9.1 Comparison of Trespasser and Non-Trespasser Fatality Rates

1994, 1995 and 1996	Amtrak	Conrail	CSX
Trespasser and non-trespasser fatalities not at grade crossings	196	108	176
Train miles (millions)	115	139	247
Fatalities per million train miles	1.70	0.78	0.71

Data are included for both trespassers and non-trespassers for two reasons. The first is that it is necessary in order to net out those fatalities that occur at grade crossings. The second is that there appears to be a systematic bias in the way the three companies distinguish between trespassers and non-trespassers.
Source: **FRA (1995a,b; 1996a,b; 1997a,b)**

population in Britain, where fencing is common, is almost identical to those in the United States and Canada, at roughly two per million. Therefore, one might argue that fencing will have no effect on trespasser fatalities. This would be supported by a comparison between Amtrak, who operate many of their trains over the fenced North-East Corridor, with Conrail and CSX who operate freight trains over primarily unfenced lines in the northeastern United States. In table 9.1 the fatality rates of trespassers and non-trespasser per train mile are shown for the three companies for the period 1994-96. Amtrak has a fatality rate twice that of Conrail and CSX. Of course, there may be legitimate reasons for this including the higher speed and quieter electric traction of some Amtrak trains, and the fact that Amtrak tends to operate in areas of higher population density.

Therefore, at one extreme, it might be argued that fencing has a negligible effect on trespassing fatalities. But it is also worth considering a more favorable estimate of possible fatality reduction from fencing the right of way in urban areas. The best estimates from existing sources (NTSB, 1978a; Pelletier, 1997) suggest that about 350 trespassing victims a year are neither residents of rural areas, undocumented suicides who would likely kill themselves in other ways, or people who already had to climbed a fence to trespass. Of this 350, a realistic estimate of the number of lives saved by fencing might be the ten percent of victims who are children, and the twenty percent of persons who so inebriated that their fence-climbing skills are diminished. This would give an estimate of 105 fatalities avoided each year.

General fencing of the railroad in urban areas would be justified if the value of an individual life saved is greater than $300 million annual cost divided by the 105 lives saved. The resulting cost per life saved is approximately $3 million. This number is in the range of figures cited in the literature, and used by the DOT as a valuation of human life (Miller et al, 1991). This would suggest that fencing is marginally justified in urban areas.

However, there are two notes of caution. The first is that both public and private safety budgets are limited. The cost per life saved by fencing is quite large. The $3 billion that would be required over a ten-year period to install fences along the entire urban right of way would be sufficient to install active warning devices at each of the 20,000 public crossings identified in the previous chapter as deserving of an upgrade, and still leave enough money over to install active warning devices at the 15,000 busiest private crossings. On my calculations such an investment would reduce the annual death toll at public grade crossings by 160 with additional lives saved at upgraded private crossings. It is reasonable to suspect that one could get twice the return from using money in this way rather than on fencing. The second caution is that the analysis is very favorable to fencing. Comparison with the British experience or the comparison between **Amtrak** and neighboring freight railroads might suggest that fencing is a futile waste of money.

10 OCCUPATIONAL INJURIES

This chapter considers the economics of occupational injuries that do not occur during train operations. These comprise a quarter of employee fatalities and eighty-five percent of employee injuries. They typically occur during maintenance of track, in railroad workshops, and when employees slip and fall. Employee fatalities and injuries that result from operational accidents are considered later in the book.

OCCUPATIONAL INJURIES AND THE LABOR MARKET

Economic models of occupational injuries have similarities and differences from the models used in previous chapters. Workplace accidents are bilateral accidents in that the care taken by both the employee and the railroad affects the probability of an accident. However, employees do have a contractual relationship with the railroad, and can influence safety by normal bargaining concerning wages and employment conditions. Companies that offer a high risk of injury may not be able to hire any labor. In contrast, trespassers and grade-crossing users are strangers to the railroad and appropriate levels of care can only be assured when there are suitable legal liability rules.

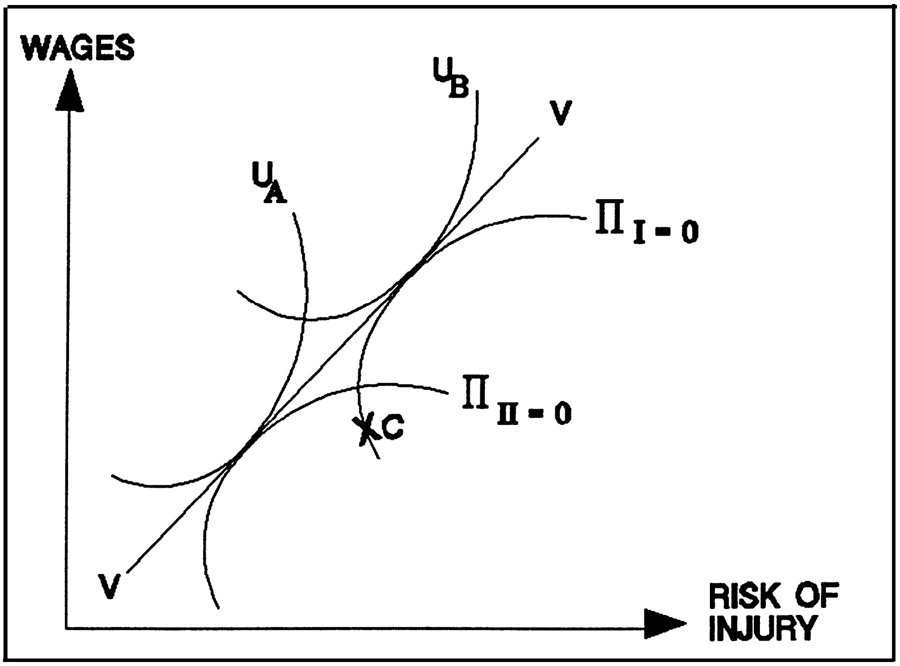
The simplest model of the labor market interaction is shown in figure 10.1. The model represents a perfectly-competitive marketplace for workers with similar skills to those required for railroad work. On the vertical axis is the wage rate and on the horizontal axis is the occupational safety risk, measured by the rate of workplace injuries. Representative firms from two industries, I and II, compete to obtain labor services.

Break-even ***iso-profit curves*** for the two industries are shown as π_I and π_{II}. A break-even iso-profit curve shows all of the combinations of wage levels and job risks that result zero industry profits. They slope upward because higher wages are only possible if the industry reduces its investment in equipment and practices that make the workplace safer.

In isolation, an industry would be indifferent as to which combination of risk and wages it offered. However, that is not the case when there are a number of industries competing for labor. For example, industry I could not choose the combination at point C because it would be unable to attract any labor. At this point, industry II offers workers better combinations of wage and risk.

If the model is expanded to represent many industries, the choices for each industry would be narrowed to just one possible combination. That would be at a

Figure 10.1: Basic Labor Market Model



point where an ***envelope*** curve is tangential to an individual industry's **iso-profit** curve. In labor economics this is known as a ***market offer curve*** and is shown as line W. Any industry offering a combination below this line would be unable to attract staff. The market offer curve will be upward sloping which means that industries that are inherently more risky must offer high wages in order to attract ***staff. This*** basic result ***in*** economics ***dates*** back ***to*** at least Adam ***Smith's Wealth of Nations*** published in 1776. He observed that occupations characterized by "hardship, disagreeableness, and dirtiness" commanded higher wages in order to attract people to work in these occupations. The wage premia paid in these industries are ***known as*** a ***compensating wage differential.***

The final element to introduce into the model is the preferences of individual workers. All workers prefer higher wages and safer working conditions, hence their preferences are toward the top left of the diagram. However, the relative valuation that individuals place on money and risk varies. In the diagram, individual A dislikes risk to a greater extent than individual B. Individual A may have a family and dependents while individual B may be single and greatly appreciates the material goods obtained from a high wage. The industries chosen by both individualswill be decided by the tangency of their ***indifference curves,*** U_A and U_B, with the market offer curve. Individual A will therefore choose to work in the less risky industry II, and individual B will choose industry I.

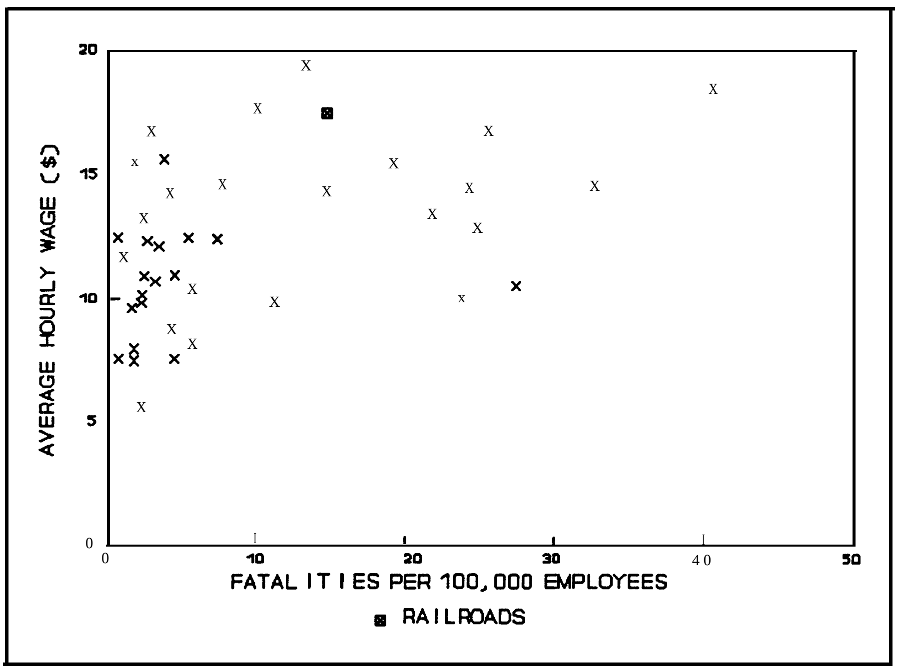
In summary, the basic model predicts that inherently more dangerous occupations will have to offer higher wage rates to attract workers. High risk-high wage occupations will optimally coexist with low wage-low risk occupations. Workers will choose between occupations based on their preferences for risk and income. If workers correctly choose the industry that reflects their preferences then the labor market will have functioned correctly.

WAGES AND RISK IN THE RAILROAD INDUSTRY

The implication of the labor market theory is that a market failure would only occur if an industry was operating below the market offer curve, that is to say the wages offered did not adequately compensate for the risks vis-a-vis other industries. Whether there is a market failure in the railroad industry can be investigated using empirical data on fatality rates per 100,000 employees and average hourly wages for a variety of different industries (Bureau of Labor Statistics, **1996b,c).**

A quick inspection of these data, shown in figure 10.2, seems to offer support for an upward sloping market offer curve. While the diagram is a simple **two-**variable plot, the positive association of fatal injury rates and wages across industries is robust even in more sophisticated regression models which incorporate other factors that influence wage rates (Ehrenberg, 1988).

Figure 10.2: Hourly Wages versus Fatality Risk for Different Industries 1995



The railroads are identified by the square symbol. Railroads workers' are among the highest paid workers in the nation, while job risks are at the lower end of those for peer industries. This would suggest that there is not a failure in the **railroad** labor market. If anything, the railroads lie above rather than on the market offer curve. Industries that lie above the curve should have little trouble in attracting staff, and should have a very low staff turnover.

Morrow et al. (1997) found evidence to support the above observations in a **survey** of 1,000 union workers at four **major** railroads. They found that "safety was the most favorably perceived aspect of the work environment by employees and the only **[job** attribute] with a mean score above the [midpoint of a scale between "strongly disagree and "strongly agree"]." There was also little evidence of considerable staff turnover. More than eighty percent of railroad workers said that they intended to remain with their current employer.

The railroads may be above the market offer curve for two reasons. The first is that common labor market failures do not apply to the railroads, and the second is that the railroads are highly unionized.

Absence of Market Failures

The labor economics literature identifies two **major** market failures. The first is a lack of labor mobility. The basic model assumes that workers are free to select between occupations and employers based on their own preferences and the wages and conditions offered. If some people are constrained either by geography or by their level of skill and education, there is the possibility that unscrupulous employers may take advantage of a captive **workforce** by offering substandard wages and/or safety conditions. Arguments of this type are not really applicable to the railroad industry. The railroad industry requires skills that are readily transferable to other occupations, and employs a workforce who are, almost by definition, quite mobile.

The second possible market failure is that workers **are** not knowledgeable about the risks of working in a particular industry or firm and therefore cannot make an informed tradeoff between workplace safety risks and the wages and benefits offered. Viscusi (1979, 1983) found that workers tend to be very well informed about workplace ***physical injuries,*** and that concerns about injury were a **major** factor in decisions to quit jobs. However, ***the same*** is not true for ***industrial illnesses.*** A typical worker will not be able to appraise the toxicity of chemicals vapors or dust that they might breathe, or the dangers to their eyesight or hearing. The consequences of exposure of this type may take years to become apparent.

Most railroad injuries result from using maintenance equipment, falling, or being struck by a train. These are the types of accidents whose probability and severity employees can quickly appraise. Illnesses such as such as hearing loss, and inhalation of solvents or asbestos, are less prevalent. In 1996, only 157 of the more than 9,000 reports of employee casualties were industrial illnesses **(FRA,** 1997a).

Effect of Unions

Railroad workers are highly unionized. Unions play an important role in keeping workers appraised of safety risks. Most unions have dedicated safety officials who are skilled in identifying dangerous situations and who report their findings to both their members and management. Market failure due to a lack of safety knowledge is less likely in a unionized setting.

Economic theory argues that unions are also have the effect of increasing safety in the workplace because the union will negotiate based on the safety desires of the ***average*** worker whereas the free market considers the economics of the *marginal* worker. Typically, the existing workforce will be older and desire less risk than the marginal **new-hire** employee who is likely to be young and single.

For example, consider two similar industries one of which is unionized and the other of which is not. If the wages were the same in the two industries, the union would argue for a higher level of job safety because it represents the interests of the ***infra*marginal** worker. Conversely if job risks are the same, the union will argue for a larger compensating wage differential. Moore and Viscusi (1990) found that workers in unionized settings received compensating wage differentials that are between ten and forty percent higher than in comparable nonunion settings.

COMPENSATION FOR WORKPLACE INJURIES

Both theoretical and empirical labor economics analyses show that workers in relatively risky occupations receive higher wages. While all the workers benefit from the increased wages, only the comparatively few who suffer injuries bear the costs of the higher risks. Prior to the twentieth century, this asymmetry of benefits and costs meant that many seriously injured workers and their families faced poverty and hardship. Workers responded by establishing mutual-aid societies, often operated by trade unions, which collected subscriptions into a fund that would provide some support to the families of members who were killed or so seriously injured that they could not return to their former jobs.

Workers had to organize to support injured colleagues because the law was heavily biased against legal claims for compensation. In theory, there was a common-law requirement that employers provide a safe work place. However, in practice, there were a number of legal maneuvers that employers could use to protect **themselves.** ***The*** first ***was the*** rule of ***contributory negligence*** which at that time applied in most jurisdictions. This rule says that employers were not liable if the worker was also negligent ***in any*** way. The second ***was the fellow-servant doctrine,*** which said that the employer was not liable if the negligence of another employee had caused the unsafe condition. ***The*** third ***was the assumption of risk*** doctrine, which said that an employer was not liable if the worker had voluntarily continued to work despite knowledge about the existence of the hazards of the workplace.

These pro-employer legal rules, coupled with dreadful tales of hardship for the families of injured workers, and the very high railroad injury rates at the turn of the twentieth century motivated Congress to implement legal reform. The ***Federal Employers' Liability Act*** **(FELA)** of 1908 dealt specifically with the railroads and eliminated the traditional defenses that employers could use. Contributory negligence was replaced by comparative negligence in most jurisdictions, which meant that even negligent employees could receive some damages if the railroad had also been negligent. The fellow-servant doctrine was eliminated, and the assumption of risk doctrine was limited and subsequently eliminated in 1939. Consequently, injured railroad workers could seek compensation by bringing legal suits against railroads.

At about the same time, reforms were introduced to provide for compensation of injured workers in other industries. This system, known as ***Workers' Compensation,*** had similar goals to the FELA but used a fundamentally different approach. It started as a scheme for federal employees in 1908, and expanded rapidly between 1911 and 1921 when it was adopted by all but six states as the primary method of compensating injured employees in both the private and government sectors. Workers' compensation is based on the legal principle of ***strict liability.*** Employers have to compensate injured employees regardless of who was at fault. Therefore, unlike FELA, courts do not have to decide on the comparative negligence of employer and employee. In effect, workers' compensation operates as social insurance scheme. To provide for settlements, employers can either self insure or pay premiums to private or state-run insurance companies.

While workers' compensation may be more generous than FELA in that even negligent employees are compensated, the scale of benefits is much lower. Both workers' compensation and FELA compensate injured employees for medical expenses and provide broadly similar benefits to cover lost income due to time away from work. But workers' compensation prohibits employees from filing suit against employers to obtain compensation for pain and suffering, or to seek additional punitive damages against employers who are willfully or wantonly negligence. FELA does not prohibit railroad workers from seeking such compensation.

In 1910 both the House and the Senate voted to convert the railroads from FELA to workers' compensation but the bill failed in conference. Attempts in the following years to change to a no-fault system were defeated by labor interests. As a result 240,000 railroad workers are covered by an entirely different system of injury compensation than the ninety million Americans covered by workers' compensation. In New York City, employees of the Long Island Railroad and Metro-North are covered by FELA, while employees of the subway are covered by workers' compensation. Railroads are covered by FELA while competing trucking companies are subject to workers' compensation.

The debate about the relative merits of FELA and workers' compensation has continued unabated. Most railroad managers would prefer that the industry was covered by workers' compensation rather than FELA. Unions have strong opinions in the opposite direction.

INJURY COMPENSATION AND BILATERAL ACCIDENTS

The most relevant question to ask in a book about railroad safety is which of FELA or workers' compensation better assures that both railroads and employees exercise due care in preventing workplace accidents. Employers can take precautions by providing good training, posting warning notices and installing machine guards. Employees also play their part by acting in a responsible manner. Nationally, at least fifty percent of industrial accidents are due to employee negligence (Viscusi, 1983). Almost twenty percent of railroad injuries are due to slipping or **falling (FRA, 1997a),** and one would imagine that falls can most easily be prevented by employees watching where they place their feet.

A model of bilateral accidents can be constructed to compare the two systems of compensation. In estimating the model, data are available on the costs of workplace accidents, and the legal and administrative fees associated with the two systems of compensation. One can also make some reasonable inferences on how the probability of an accidents varies with the amount of care taken by both parties. What is generally unknown is the costs that both parties incur in taking care.

Table 10.1: Costs of Workers Compensation Versus FELA

		Workers' Compensation	FELA
1	Covered employees[1]	90 million	240,000
2	Annual settlement payments'	$35 billion	$911 million
3	Average settlement per covered employee	$400	$3,800
4	Claims rejected or reduced due to employee negligence per covered employee (25 %[1] of line 3)	-	$950
5	Proportion of payout in litigated cases	30%'	75%'
6	Plaintiffs legal expenses per employee (25 %[3] of line 3 multiplied by line 5)	$30	$710
7	Net settlement per covered employee (line 3 less line 6)	$370	$3,100
8	Employers' administrative and legal expenses	$27 billion'	$170 million'
9	Employers' administrative and legal expenses per covered employee	$300	$710

Sources: [1] Transportation Research Board (1994) [2] GAO (1996)
[3] Barth and Telles (1992) [4] Association of American Railroads

Data from recent research studies on compensation payments, and legal and administrative fees for both workers' compensation and FELA are shown in table 10.1. Because injured railroad workers can sue for pain and suffering as well as medical expenses and lost wages, average settlements per covered employee, shown in line three, are almost ten times those under **workers'** compensation. This finding is in line with more detailed research studies (GAO, 1986; Transportation Research Board (TRB), 1994). Of course, settlements under FELA do not **reflect** total employee pain and suffering because courts can reduce or reject claims due to employee contributory negligence. Based on evidence **from** TRB **(1994),** one can estimate that employees are currently uncompensated for an amount equivalent to a quarter of the average FELA settlement.

Because FELA is an adversarial judicial system whereas workers' compensation is an administrative insurance system, the legal and administrative expenses incurred by railroads and injured employees (the combination of lines six and nine) are four times higher under FELA than under workers' compensation.

Currently, the probability that a railroad worker suffers an injury in a given year is one in twenty-five, or 0.04 **(FRA,** 1997a). What would happen to this probability if railroads and/or employees took less than their current level of care is speculative. One could argue that if neither party took care, the probability of a workplace accident would be the 0.25, which is what it was in 1920. A reasonable assumption is that care taken by employees can reduce the workplace accident rate by half (Viscusi, 1983). Therefore one could speculate that the probability of a workplace accident would be **0.125** if the railroad took less care and employees took their current level of care, and 0.08 if the railroad took their current level of care and the employees took less care.

The preceding information is incorporated into a bilateral accidents model shown in table 10.2. The model represents the expected costs of workplace accidents for a typical railroad worker in a given year. There are two changes **from** the model used in earlier chapters. The first one separates the injury costs to employees into costs associated with medical expenses and lost wages, and those due to pain and suffering. The second is the addition of the legal and administrative costs of adjudicating claims.

The last line of table 10.2 shows the current situation where both the railroad ***(RR)*** and ***the*** employee ***take*** their ***current level of care. The expected*** medical expenses and lost wages are approximated by the average workers' compensation settlement shown in line seven of table 10.1. An assumption will be made that the railroads bear equivalent costs to hire a replacement worker to cover the duties of the injured employee. The expected compensated cost of pain and suffering is approximated by the difference between average workers' compensation and FELA settlements, shown on line seven of table 10.1. The expected uncompensated cost of pain and suffering is approximated by the rejected or reduced FELA claims shown in line four of table 10.1.

If either or both of the parties do not take care, then the probability of an accident will increase, and the expected accident costs will increase proportionately. Of course, changes in the relative levels of care taken will affect FELA court

Input Measures Versus Output Measures

The traditional objection to use of measures of accidents to identify delinquent railroads is that it is inherently an ***ex-post*** identification of myopic firms. The FRA can **only** observe which railroads are myopic ***after*** the accident rate has increased. Ideally one would wish to detect myopic railroads prior to the point at which the number of accidents increases. Myopia is caused when a railroad starts to weight current costs more heavily than future costs. This is mainly occasioned by **short-**term financial expediency by the railroad which might be caused by a decline in revenues, possible bankruptcy, or the wish to look attractive for stock offerings or if they are a takeover target. The FRA would probably want to have a system which alerts them to changes in financial conditions of individual railroads. In addition, the FRA might develop an information system on safety inputs that might be used to alert them to railroads that do not seem to be spending as much on track maintenance as they used to or who are allowing the average age of their locomotives to increase. Information on staff turnover might be used as an indication of railroads whose working conditions have deteriorated so that employees wish to resign. A legacy of the many years of regulation is that the largest firms in the industry are already required to submit much of this information to the government.

Of course, the link between financial condition or measures of safety inputs and the number of accidents is tentative, and not well understood. It is possible that financial measures and safety-input measures could decline without affecting safety performance. Conversely, safety performance can decline for reasons that are not captured by financial and input measures. For this reason the FRA would also wish to have measures of accident performance in its information system.

There is an additional benefit from defining minimum acceptable **accident-performance** measures. Responsible firms will be deterred from myopic behavior if there are clearly stated minimum performance standards that they can meet that would obviate scrutiny by the FRA. From a societal point of view it is much more beneficial to state these minimal objectives in terms of safety outputs rather than by the existing system where acceptable performance is stated in terms of the minimum quality and quantity of safety inputs. The benefit comes from the ability of railroads to use their managerial ability to achieve at least the minimum level of safety by using the most efficient combination of safety inputs.

Defining Measures of Safety Performance

What accident measures should be used? There are a number of considerations that will help define the best measures.

Timeliness*:** One cannot escape the fact that accident data is an ***ex-post identification of myopia. This problem can be minimized if one measures accidents that occur relatively frequently. It is pointless to use the occurrence of a major catastrophe as the catalyst for identifying delinquent railroads. These events occur rarely, and to react only after such an event can certainly be described as "closing the stable door after the horse has bolted." The measures of safety performance should use a wider definition of accidents. Currently a collision or derailment is reportable to the FRA if it results in a fatality, or an injury or more than $6,300 in damage to railroad property. The average Class I railroad has more than 130 reportable collisions and derailments a year. With this frequency of accidents, the FRA should be able to identify an upward trend for any railroad relatively quickly, and hopefully prior to the incidence of major catastrophes.

***Measuring different risks*:** Separate measures should be developed for each of the major risks associated with railroading. It would seem sensible to separate out the risks of collisions and derailments from those of employee injuries or grade-crossing accidents or trespasser fatalities. Each of these different types of risk have different causal factors and demand different responses.

***Data Integrity*:** To make the analyses meaningful, one needs measures of safety that are reported consistently, and cannot easily be falsified. Consequently, measures need to be relatively simple, and not require judgement on the part of the railroad as to whether to report an accident. A GAO audit (1989b) of five railroads found serious underestimating of the number of lost workdays by injured employees and inaccurately estimating of the property damage from train accidents. All but one of the railroads was found to lack a system for tracked the number of days that an employee was away from work following an injury. The magnitude of the underreporting was large. The railroads reported 2,176 lost workdays by injured employees, whereas the GAO determined that in actuality the figure was 8,023. The GAO also looked at unreported cases of injured employees, and found that twelve percent of cases were serious enough to need to be reported. The moral is that it is more reliable to measure the number of injured employees rather than to try to use the more sophisticated measure of total workdays lost.

A similar problem was found with the estimates of property damage in accidents. With the exception of one of the railroads, the GAO found that estimates of property damage were made at the scene of an accident and the degree of understating of property damage was in the range of fifty to sixty percent. As a result, some property-damage-only accidents were not reported even though they should have been had property damage been estimated properly. Again this emphasizes that measures should be based on criteria that do not require too much judgement from the officials completing accident reports.

Of course, a railroad that decides to cheat will be predisposed to cover up that cheating by deliberately underreporting accidents. This is obviously undesirable from two points of view. The first is that the FRA might be misled into not noticing that the railroad is cheating. The second is that a railroad management that communicates to its employees that they should be "careful" in deciding whether to report accidents is implicitly communicating that senior management does not take safety very serious, and that may cause employees to be less diligent than they might otherwise be. Moses and Savage (1994) found that the truck carriers that did not comply with government regulations on accident reporting had a worse accident rate even on the records of accidents found by federal inspectors during safety audits. The magnitude of the effect was large. Carriers who were deficient in reporting had an accident rate nine times higher than those that did report. Accident measures should be chosen in such a way that it is difficult for railroads to falsify reports, and the FRA as part of its delinquency system will have to audit railroads to ensure that there is not deliberate underreporting. It may be necessary to increase the penalties for false reporting.

changes ***in exposure to risk: The*** FRA will need to be sensitive to changes in exposure to risk. Railroads vary in size, and even an individual railroad can change its size from year to year. During economic upturns, more train miles will be run and the number of accidents will increase. Therefore, for each measure of adverse safety occurrences there needs to be an appropriate measure of the exposure of the railroad to that risk.

Data variability: To be able to draw meaningful comparisons between one year and the next, the FRA should choose measures that do not suffer from wide fluctuations. For example, it might be intuitively appealing to define measures that combine severity of accidents with frequency of occurrence. Accidents that cause fatalities or evacuation of many' people from an accident involving hazardous materials might be given greater weight than one that only involves property damage. However, such measures are also problematic. The problem is that accidents with serious consequences occur rarely. Hence the annual data will be ***skewed*** by the years with large catastrophes and consequently the calculated ***variance*** of the data will be large. As described by elementary statistical theory, the larger the variance in the data, the more difficult it is to determine whether the number of accidents ***in*** a given year is ***statistically significantly different*** from the historical average for that railroad. It may be more statistically powerful to use a simple measure such as the number of collisions and derailments rather than attempt to use a more sophisticated measure that incorporates the severity of the accident.

Analyzing Measures of Safety Performance

Of course, there will still be some variability in the data from year to year because while one can anticipate that a certain amount of preventive effort will result in a certain average number of accidents a year, one cannot define exactly when an accident will occur. Pure chance plays a role. A railroad may be "lucky" in not having very many accidents one year, but consequently have more accidents in a subsequent year. The FRA would clearly wish to be intelligent enough to incorporate these natural year-to-year fluctuations into their analytical process.

Fortunately statistical theory provides the necessary tools. Statisticians usually claim that accident occurrence is explained by the Poisson distribution. The probability that a railroad will have x adverse safety occurrences in a given year is given by the formula:

$$\textit{Probability } (x \textit{ occurences}) = \frac{e^{-\lambda M} (\lambda M)^x}{x!} \tag{20.1}$$

where λ is the probability of an occurrence (eg., the derailment and collision probability per train mile), and M is the exposure to occurrences (eg., annual train miles). The expected number of occurrences in a given year is obviously λM. The value of λ is determined by the preventive efforts made by the railroad. The more preventive efforts undertaken, the less will be the value of λ.

The actual number of occurrences **observed** is unlikely to be exactly AM, but rather will be distributed around λM as described by the Poisson distribution. The problem facing the FRA is to determine whether the number of occurrences observed for a particular railroad in a particular year has deviated ***upward*** from the mean number expected for that railroad. Statisticians make that determination by ***using*** a ***one-tailed significance test.*** Statisticians look to see how far the observed value is from the mean. It is called a one-tailed test because the FRA is only interested in railroads whose safety performance is declining, that is to say that the observed number of occurrences is greater than the mean.

Of course, almost any level of observed number of occurrences is possible, and is consistent with the mean given the inherent variability in the Poisson process. However, the further the observed number is from the mean, the less likely it is to occur. For example, consider a railroad that averages 100 collisions and derailments a year? Equation (20.1) determines that this railroad will have more than 107 accidents one year in every four, will have more than 117 accidents one year in every twenty, and more than 120 accidents one year in every forty.

How many accidents does this railroad need to have in a given year before the FRA suspects that the preventive efforts of the railroad have declined and the expected number of accidents is greater than **100?** There is not a clear-cut answer to this question. Clearly one increases the chance of detecting a myopic railroad if the ***critical value*** of the number of accidents was set at 107. This is technically known as minimizing the chance of a ***type II*** error. However, one also stands a one in four chance of falsely accusing a responsible railroad. This is known as a ***type*** Z error. The reader will appreciate that there is a tradeoff between the sizes of the type I and type II errors. For this reason, statisticians typically use the five-percent significance level, which is to say that critical value above which the count of occurrences would only fall outside by pure chance once every twenty years.

The critical values for three levels of significance are shown in table 20.2 for differing levels of the expected number of occurrences (ie., AM) between one and 1,000 per year. The critical value is also expressed as the percentage variation above the mean. Focussing on the middle column representing the five-percent significance level, one can observe an important implication. For a railroad that only averages three occurrences a year, one would need to observe six occurrences before one ***can be statistically confident*** that the railroad is offering reduced safety. This implies that the accident rate has doubled. Yet for a larger railroad that averages 200 occurrences a year, the number only has to increase by twelve percent before one is statistically confident that safety has declined. Clearly, statistical tests based on the Poisson distribution are more powerful, and more likely to detect myopia for the larger railroads.

Table 20.2: Critical Values for One-Tailed Statistical Significance (with percentage variation above the mean)

Mean Number of Annual Occurrences	One-Tailed Significance Level		
	25%	5%	2½%
1	2 (+100%)	2 (+100%)	3 (+200%)
2	3 (+50%)	5 (+150%)	5 (±150%)
3	4 (+33%)	6 (+100%)	7 (+133%)
4	5 (+25%)	8 (+100%)	8 (+100%)
5	6 (+20%)	9 (+80%)	10 (+100%)
10	12 (+20%)	15 (+50%)	17 (+70%)
20	23 (+15%)	28 (+40%)	29 (+45%)
30	34 (+13%)	39 (+30%)	41 (+37%)
50	55 (+10%)	62 (+24%)	64 (+28%)
100	107 (+7%)	117 (+17%)	120 (+20%)
200	209 (+5%)	223 (+12%)	228 (+14%)
300	312 (+4%)	329 (+ 10%)	334 (+11%)
500	515 (+3%)	537 (+7%)	544 (+9%)
1000	1021 (+2%)	1052 (+5%)	1062 (+6%)

It is probably fair to say that for measures of safety performance that occur less than fifty times a year, the size of the year-to-year variation is so large in percentage terms that it may be difficult in practice to draw meaningful statistical conclusions. Fortunately, the situation is less discouraging if a railroad is observed over multiple years. Consider the twenty-five-percent significance level. A railroad would have an occurrence count above this level by pure chance one year in every four. However, if the railroad falls above the critical value for two years in a row, then the probability that this event will occur purely by chance, and not due to poor safety precautions by the railroad will be $\frac{1}{4}^{2}$ or one chance in sixteen. The probability that the railroad would fall above the critical value by pure chance for three years in a row is $\frac{1}{4}^{3}$ or year in sixty-four, a very small probability. On this

Table 20.3: Average Number (and Range) of Accidents 1995

	Collisions and Derailments	Employee Fatalities and Injuries	Trespasser Fatalities	Grade Crossing Accidents
Class I	137 (41-353)	579 (84-1273)	39 (l-85)	304’ **(47-62**1)
Class II Freight	10 (1-39)	31 (5-139)	1 (O-12)	10 (O-78)
Class II Passenger	5 (O-17)	236 (5 l-558)	9 (1-27)	7 (O-15)
Class III[2]	0.13	4.37	0.05	1.28

[1] Excludes Amtrak who operate over other company’s lines [2] Range is not reported
Source: **FRA (1996a)**

basis it is possible that meaningful statistical inference can be drawn on railroads who average as few as five or six occurrences a year.

To consider the practical implications of the above statistical reasoning, consider the frequency with which four major types of safety problems occur. The four types are: collisions and derailments, employee injuries and fatalities, trespasser fatalities away from grade crossings, and accidents at grade crossings. Table 20.3 shows the average annual number of these safety occurrences in 1995 for four different categories of railroads: Class I, Class II freight, Class II commuter passenger, and Class III. Also shown is the range of the number of these occurrences for the first three categories of railroads. The published FRA data does not break down the number of occurrences by individual railroads for Class III railroads.

Statistical analyses of occurrence rates could certainly be possible for looking at collisions and derailments, employee casualties and grade crossing accidents of Class I railroads. Trespasser fatalities on individual Class I railroads could be analyzed if looked at over several years. The same is likely to be true for collisions and derailments, employee casualties and grade crossing accidents for the Class II railroads. However, it is unlikely that statistical techniques will be suitable for Class III railroads. An average-sized Class III railroad injures four employees a year, has one grade-crossing accident a year, kills a trespasser once every twenty years and has a collision or derailment once every seven-and-a-half years.

TIME-SERIES ANALYSIS OF ACCIDENT RATES

This section takes the theoretical discussion of the previous section and applies it to data on Class I and II railroads in the early 1990s. The objective of the analysis is to **observe** whether the performance of individual railroads was worse in 1994 and 1995 than it was in the earlier part of the decade. Analysis of this type will permit identification of those railroads which the FRA might suspect are indulging in reduced prevention.

Two measures of safety performance are used: the number of collisions and derailments and the number of employee fatalities and injuries. These are aspects of safety which one **might** assume are under the control of railroad management, unlike trespasser and grade-crossing accidents which are affected by the geographic location of the railroad.

The first step in the analysis is to estimate the expected number of occurrences that each railroad would have in 1994 or 1995, based on its performance in 1991-93. This is calculated in such a way to take into consideration changes in the exposure of the railroad to risk, and changes in the general rate of collisions and derailments or employee casualties in the industry that might indicate changes in technology or working practices that are common to all railroads. For example, the formula that is used for predicting the occurrences on railroad i in 1994 is:

$$\textit{Expected number of occurances}_{i,94} = \lambda_{i,91-93} * M_{i,94} * \frac{\lambda_{k,94}}{\lambda_{k,91-93}} \qquad (20.2)$$

where $\lambda_{i,91-93}$ is the occurrence rate for railroad i in the years 199 1-93 ;

$M_{i,94}$ is the amount of exposure to the risk in year 1994;

$\lambda_{j,94}$ is the overall occurrence rate for that subsection of the industry to which railroad i belongs in 1994. For this purpose the industry was split into three segments: Class I railroads, Class II freight railroads, and Class II commuter railroads; and

$\lambda_{j,91-93}$ is the overall occurrence rate for that subsection of the industry to which railroad i belongs in 1991-93.

One problem was encountered during the analysis. The Burlington Northern Railroad managed to improve its employee fatality and injury rate significantly from 1991-93 to 1994 and 1995. Because this railroad is so large, it reduced the Class I average employee casualty rate so much that it made it appear that all of the other Class I railroads were getting worse. In actuality, the employee casualty rates of most of the other Class I railroads were also declining, and were doing so from a much lower level. Therefore expected employee casualties for the Class I railroads were not adjusted by the final term in equation (20.2).

The actual number of occurrences in 1994 and 1995 is then compared with the relevant predicted number. The ratio of the actual number of occurrences to the predicted number is shown in table 20.4. A value of greater than 100 indicates that the actual number of occurrences was greater than that predicted. Table 20.2 is then used to see if the observed number is above the critical value based on the assumption that the predicted value is the mean value shown on the first column.

Table 20.4 Time-series Analysis of Individual Railroads

	Ratio of Actual to Predicted Occurrences			
	Collisions & Derailments		Employee Casualties	
	1994	1995	1994	1995
Class I Railroads				
Amtrak	**118***	103	**110****	**112****
Atchison, Topeka and Santa Fe	85	**110***	48	31
Burlington Northern	113”	127”	38	28
Chicago and North Western	107	-	79	
Consolidated Rail Corp.	**112***	**106***	88	64
CSX Transportation	80	79	73	52
Grand Trunk Western	**122***	**111***	87	79
Illinois Central	88	66	73	58
Kansas City Southern	**301****	**286****	82	67
Norfolk Southern	101	85	77	65
Soo Line	99	95	93	89
Southern Pacific	91	97	80	63
Union Pacific	89	81	67	54
Class I average	85	83		
Class II Freight Railroads				
Alaska	49	119	84	103
Alton and Southern	96	61	105	164”
Bangor and Aroostook	44	45	80	99
Belt Railway of Chicago	**225****	**141****	**191****	53
Bessemer and Lake Erie	314	398	101	**211****
Birmingham Southern	0	147	65	80
Chicago, Central and Pacific	77	66	**139****	**112***
Cuyahoga Valley			84	
Dakota, Minnesota and Eastern	109	93	67	96
Delaware and Hudson	115	**163***	91	**126***
Duluth, Missabe and Iron Range	**148***	**185***	83	102
Elgin, Joliet & Eastern	**137***	**236****	106	59
Florida East Coast	51	**150***	**180****	**212****
Gateway Western	112	67	73	95
Houston Belt & Terminal	71	62	**132***	101
Indiana Harbor Belt	80	**115***	**134****	**151****
Montana Rail Link	82	86	56	71
Paducah and Louisville	0	93	91	103
Port Terminal (Houston, TX)	65	21	79	74

Table 20.4 (Continued)

	Collisions & Derailments		Employee casualties	
	1994	1995	1994	1995
Springfield Terminal	36	**8**	56	**69**
Terminal Railroad of State Dock	110	101	42	99
Texas Mexican	65	**-**	**151****	**-**
Union Railroad (Pittsburgh)	**190***	**223****	105	87
Wheeling and Lake Erie	75	**136***	50	56
Wisconsin Central	117"	**115***	**131****	**141****
Class II freight average	100	89	96	87
Class II commuter Railroads				
Long Island	184""	**135***	89	78
Metro North	114	86	104"	92
New Jersey Transit	68	48	107	41
Northeast Illinois Regional	67	**241***	**110***	**113***
Northern Indiana Commuter	137	0	**118***	**129***
Port Authority Trans Hudson	0	148	87	85
Southeastern Pennsylvania	27	40	**142****	**128****
Class II commuter average	108	99	93	79

If the actual number of occurrences was greater than the twenty-five percent critical value, an **"*"** is placed next to the ratio. If it exceeded the five-percent critical value, a **"**"** is placed next to the ratio.

A decision rule is then necessary to decide which railroads had significantly worse performance. One rule might be that a railroad is suspected of deteriorating safety if it has either (a) one year in which the observed number of occurrences falls above the five-percent critical value, or (b) the observed number of occurrences falls outside the twenty-five-percent critical value in both years. The probability of a Type I error, which is to say that a railroad that is not deviating from past performance is falsely accused is one in twenty for the first criteria and one in sixteen for the second criteria.

Among the Class I railroads the Kansas City Southern shows the worst deterioration in the number of collisions and derailments, with the Burlington Northern, Conrail, and the Grand Trunk Western also showing statistically significant declines. Only Amtrak appears to have significantly worse employee fatalities and injuries compared with earlier in the decade.

Among the Class II freight railroads the Belt Railroad of Chicago; the Duluth Missabe and Iron Range; the Elgin, Joliet and Eastern; the Union Railroad of

Pittsburgh; and the Wisconsin Central had statistically higher numbers of collisions and derailments than earlier in the decade. Worsening employee casualties are found at the: Belt Railway of Chicago; Bessemer and Lake Erie; Chicago, Central and Pacific; Florida East Coast; Indiana Harbor Belt; Texas Mexican; and Wisconsin Central.

Among the Class II commuter passenger railroads the Long Island Railroad had an increasing number of collisions and derailments and increased employee casualties were at the Northeast Illinois, Northern Indiana, and Southeastern Pennsylvania systems.

CROSS-SECTIONAL ANALYSIS OF ACCIDENT RATES

In the long run the FRA would only be interested in identifying railroads that are deviating from their, presumably satisfactory, past safety performance. However, at least in the short run, the FRA might also wish to identify which railroads have the worst safety performance ***per se.*** While the FRA should clearly be interested in any railroad whose performance is deteriorating, it should give high priority for further investigations to those railroads that have poor records to start with.

Prior to a formal analysis, it is instructive to look at some graphical plots for Class I and II railroads in 1995. Figures 20.1 through 20.4 plot the accident rates for four measures of safety against exposure. The four measures are: collisions and derailments per million train miles, employee fatalities and injuries per million employee-hours, trespasser fatalities per train mile, and crossing accidents per crossing. The Class I railroads are shown as the squares, the Class II freight railroads as the triangles and the Class II commuter passenger railroads as the crosses. The horizontal lines represent the average accident rate for each of the three types of railroads.

Turning first to the rate of collisions and derailments, the commuter railroads have the lowest rate, at only forty percent of that of the Class I railroads. The Class II railroads have an average collision and derailment rate equivalent to the worst of the Class I railroads. Of course, a major explanation is that these railroads are involved in relatively more switching. Three Class II freight railroads have a collision and derailment rate more than three times the average. One of these, the Belt Railway of Chicago has a rate of almost nine times the average and is not shown in figure 20.1.

Employee fatalities and injuries per million employee hours are shown in figure 20.2. The Class I railroads have the lowest rate at 9.5 fatalities and injuries per million employee hours. Class II freight railroads have injury rates about seventy percent higher than the Class I railroads. In general the injury rates for the various Class II railroads are closely grouped around the mean with no railroad having an injury rate of more than twice the mean. Commuter railroads have an injury rate two-and-a-half times that of the Class I railroads.

The rate of trespassing fatalities per train mile, shown in figure 20.3, confirms earlier analyses of the trespassing problem. Trespassing is primarily an urban

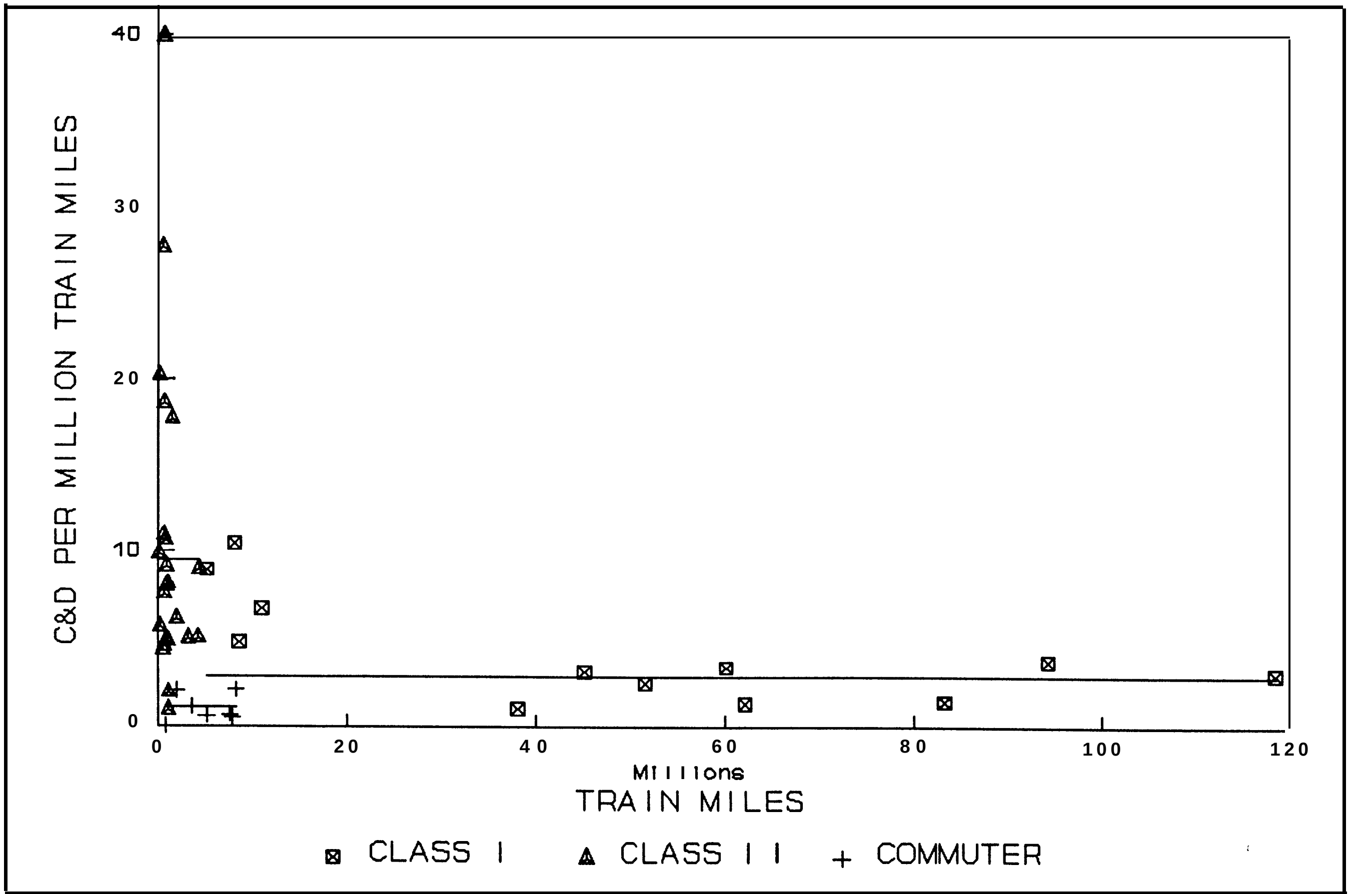


Figure 20.1: Collisions and Derailments per Million Train Miles 1995

Figure 20.2: Employee Casualties per Million Employee Hours 1995

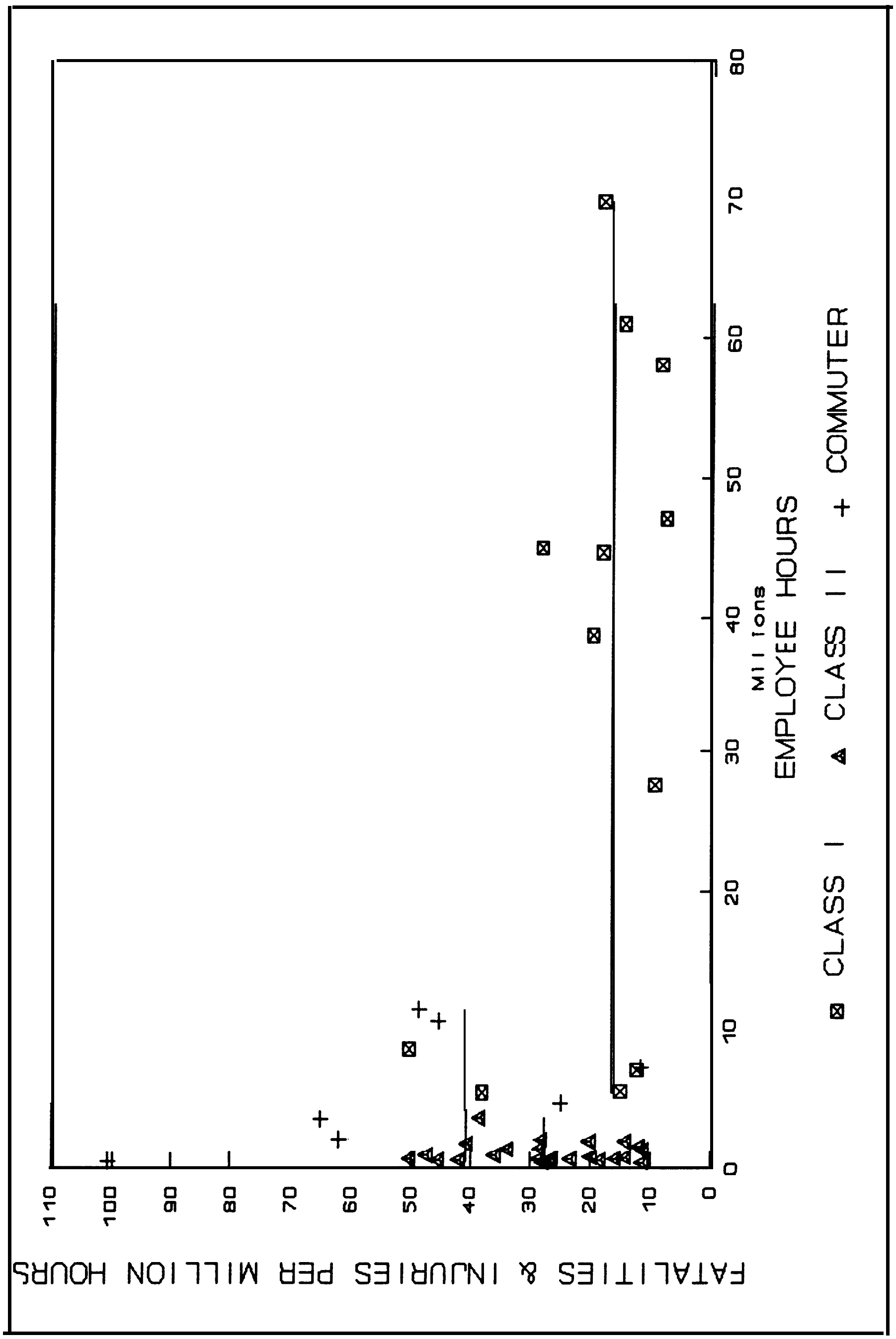


Figure 20.3: Trespasser Fatalities per Million Train Miles 1995

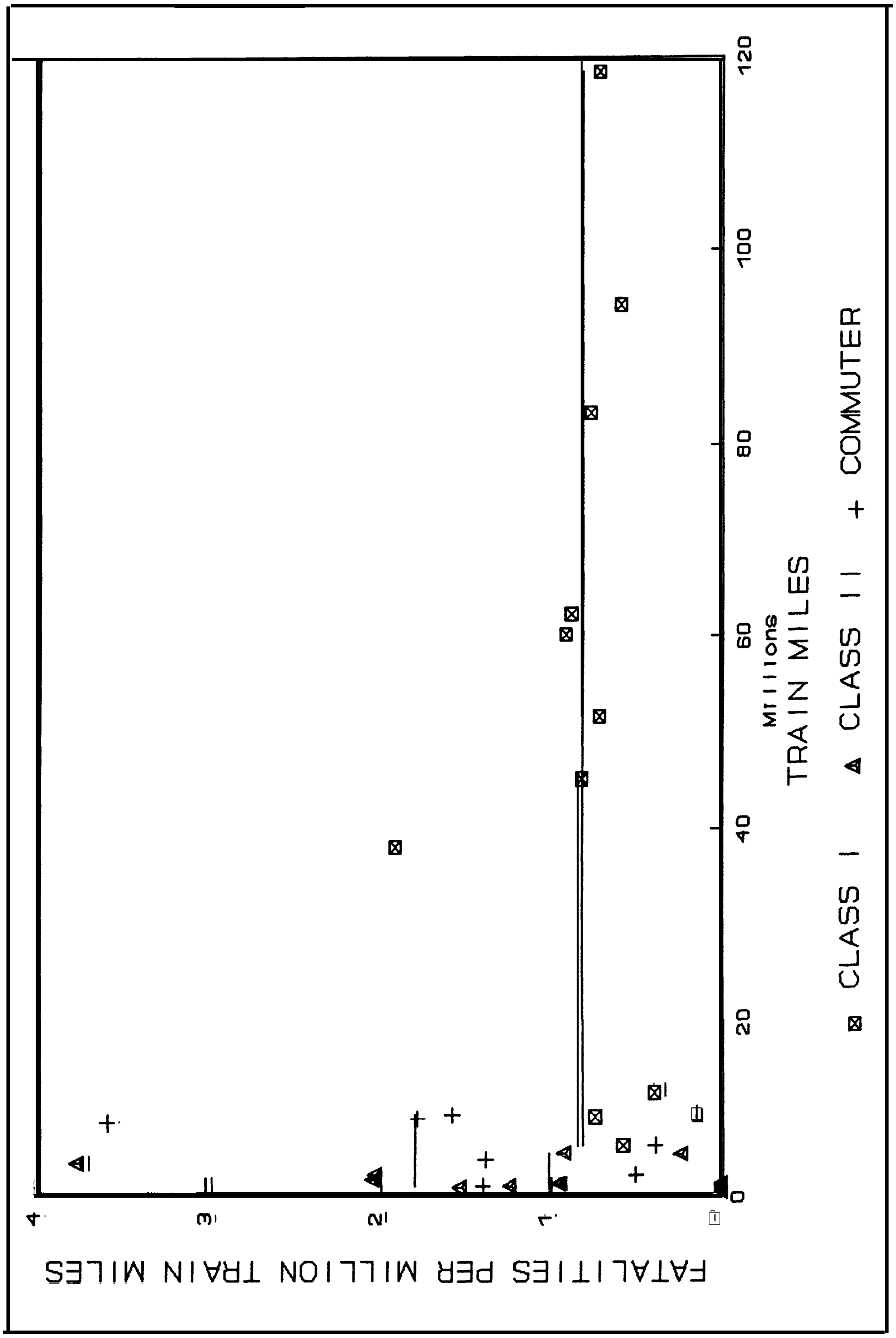
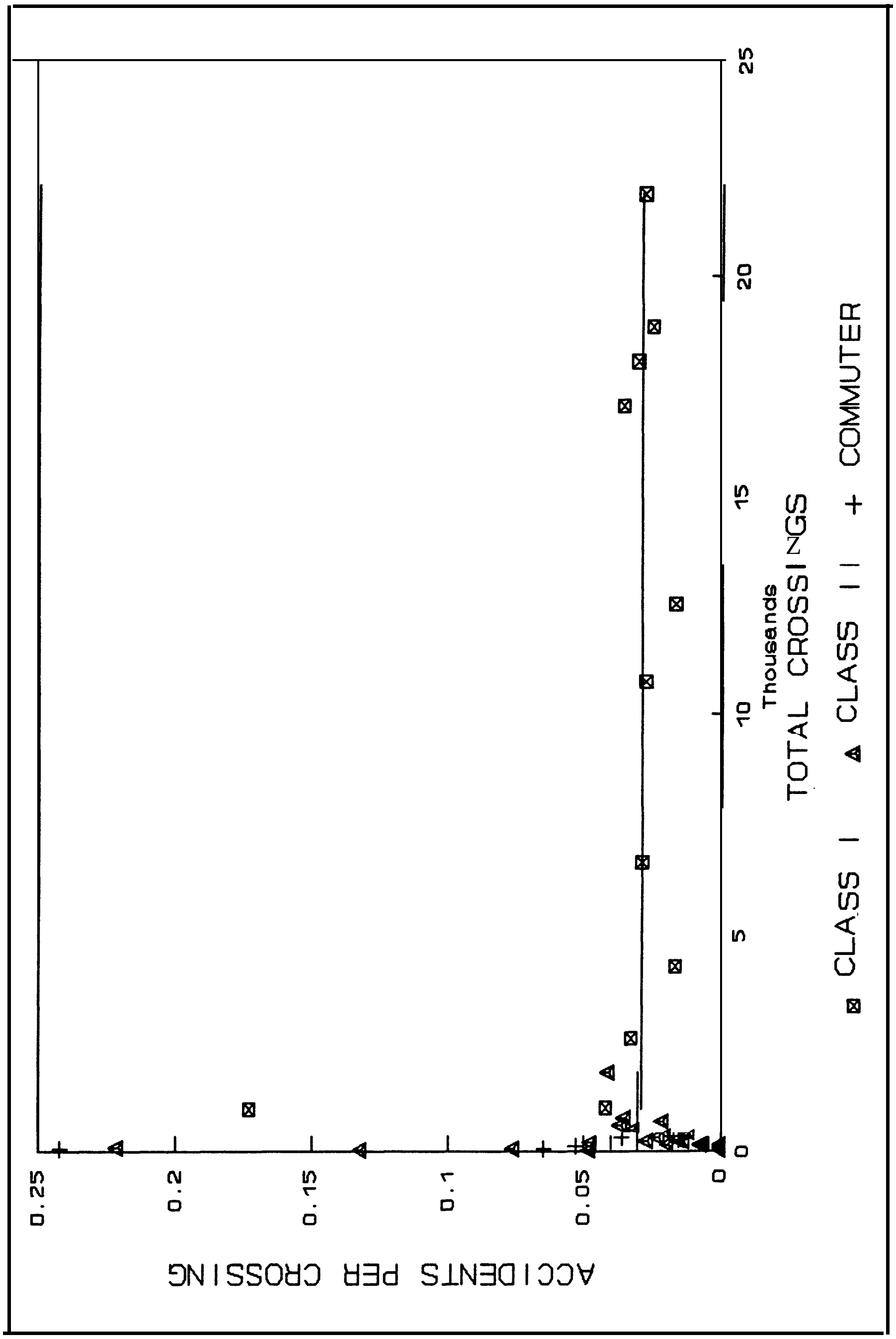


Figure 20.4: Crossing Collisions per Crossing 1995



problem and the fatality rate for commuter railroads is twice that for the freight railroads. Among the Class I railroads, Amtrak has a trespassing fatality rate equal to that of the commuter railroads. The only other railroad that stands out is the Florida East Coast which has a fatality rate three times higher than average.

Calculating of the rate of grade crossing accidents is problematic. The measure used in figure 20.4 is grade-crossing accidents per crossing. Problems can emerge in cases where a railroad operates extensively over other companies' tracks. A good example is Amtrak which has many grade-crossing accidents involving their trains, but has relatively few crossings on the stretches of lines that they own. Amtrak is not shown in figure 20.4. Another example is the commuter-passenger company in Chicago, and also the Indiana Harbor Belt Railroad. The rate of accidents is remarkably consistent across the three types of railroads at about three to four accidents per 100 crossings per year. The only railroads that really seem to stand out with unusually high accident rates are the Kansas City Southern, the Belt Railway of Chicago, and the Port Terminal Railroad Association of Houston, Texas.

A more formal analysis can be conducted using regression techniques. The analysis is confined to collisions and derailments, and employee fatalities and injuries. From the previous discussion it is clear that there would be very little to be gained, vis-a-vis a purely graphic analysis, from conducting any regressions on the rates of trespassing fatalities or crossing accidents.

The cross-sectional analysis was conducted for 1995. The predicted number of collisions and derailments and employee fatalities and injuries were obtained by estimating regressions on the occurrence rates for the forty-two Class I and II

Table 20.5: Regression Estimates of Predicted Safety Performance 1995

	Collisions and Derailments per Million Tram Miles		Employee Casualties per Million Employee Hours	
	Coeff.	t statistic	**Coeff.**	t statistic
Intercept	4.12	1.63	25.25	2.83
Yard miles/train miles	19.80	3.10	-	
Passenger dummy	-		23.05	3.55
Adjusted R^2	0.17		0.22	
Observations	42		42	

railroads. The regression predicting collisions and derailment contained a variable representing the proportion of train miles represented by switching, and the equation predicting employee casualties contained a dummy variable indicating whether the railroad was a commuter passenger railroad or Amtrak. These variables were chosen because they are ***exogenous*** characteristics of the railroads. They cannot be chosen or altered by the railroad's management. One variable that is deliberate *not* in the regressions is railroad size. The whole purpose of the analysis is to identify the worst railroads, and one would therefore not wish to explain away the fact that small railroads have a higher occurrence rate.

The results of the regressions are shown in table 20.5. The variables are strong, statistically-significant predictors of the occurrence rate. However, the regressions only explain about a fifth of the variation in the occurrence rates, which implies that there are other factors at work. The regression results are used to predict the number of accidents that a railroad should expect to have. For example, the expected number of collisions and derailments for railroad i is given by:

$$\left(4.12 + \left(19.80 * \frac{YardMiles_i}{TrainMiles_i}\right)\right) * TrainMiles_i \qquad (20.3)$$

The actual number of occurrences for each railroad is then compared with the predicted number. This is shown as a ratio in table 20.6. A ratio of greater than 100 indicates that the railroad has a greater number of accidents than that predicted. Of course, a railroad might have a higher than expected number of accidents in 1995 simply because of the random year-to-year fluctuations explained by the Poisson distribution. For that reason a five-percent significance test was applied using the data from table 20.2. The predicted number of occurrences was taken to be the mean number in the first column of table 20.2. Railroads who had a higher number of occurrences in 1995 than the five-percent critical value have "**" placed next to their data in table 20.6.

There are four railroads whose collisions and derailments are statistically significantly greater than would be expected. They are the Kansas City Southern, the Belt Railroad of Chicago, the Dakota, Minnesota and Eastern, and the Indiana Harbor Belt. The latter three railroads have actual numbers of collisions and derailments many times the predicted number. The two Chicago area switching railroads have four times more collisions and derailments than would be expected. The Dakota, Minnesota and Eastern, a ten-year-old company, has a rate almost ten times that which would be expected. Twenty-two of the twenty-six collisions and derailments for this company were derailments caused by defective track.

There are more railroads whose number of employee fatalities and injuries are statistically greater than the predicted value. In part the greater number of railroads thus identified is explained by the fact that employee casualties are more numerous than collisions and derailments and thus the critical value is proportionately closer to the predicted value. Also, the equation used for prediction is much simpler than that used for predicting collisions and derailments in that it only contains an intercept term and a dummy variable. Among the Class I railroads, the Grand

Table 20.6: Cross-Sectional Comparison 1995

	Ratio of Actual to Predicted Occurrences	
	Collisions & Derailments	Employee Casualties
Amtrak	20	59
Atchison, Topeka and Santa Fe	42	37
Burlington Northern	52	58
Consolidated Rail Corp.	39	72
CSX Transportation	20	34
Grand Trunk Western	90	**150****
Illinois Central	83	49
Kansas City Southern	**145****	60
Norfolk Southern	18	30
Soo Line	82	**199****
Southern Pacific	52	78
Union Pacific	48	72
Alaska	64	**142****
Alton and Southern	44	112
Bangor and Aroostook	65	**199****
Belt Railway of Chicago	**389****	44
Bessemer and Lake Erie	100	92
Birmingham Southern	130	110
Chicago, Central and Pacific	168	**188****
Dakota, Minnesota and Eastern	**967****	**180****
Delaware and Hudson	134	112
Duluth, Missabe and Iron Range	132	134
Elgin, Joliet & Eastern	141	47
Florida East Coast	65	79
Gateway Western	55	106
Houston Belt & Terminal	34	79
Indiana Harbor Belt	**429****	**160****
Montana Rail Link	105	111
Paducah and Louisville	56	**166****
Port Terminal (Houston, TX)	8	62
Springfield Terminal	15	56
Terminal Railroad of State Dock	116	72
Union Railroad (Pittsburgh)	84	104
Wheeling and Lake Erie	152	56
Wisconsin Central	117	**152****
Long Island	47	100

Table 20.6 (Continued)

	Collisions & Derailments	Employee Casual ties
Metro North	12	94
New Jersey Transit	12	24
Northeast Illinois Regional	24	51
Northern Indiana Commuter	0	**209****
Port Authority Trans Hudson	30	**128****
Southeastern Pennsylvania	14	**135****

Trunk Western and the Soo Line have higher than predicted employee casualties. Among the Class II freight railroads the Alaska, Bangor and Aroostook; Chicago, Central and Pacific; Dakota, Minnesota and Eastern; Indiana Harbor Belt; Paducah and Louisville; and the Wisconsin Central have statistically-significant elevated employee casualties. The same is also true of the Northern Indiana, Port Authority Trans Hudson, and Southeastern Pennsylvania commuter passenger systems.

This, albeit very simple, type of analysis has identified two railroads that do poorly on both measures of safety, and a further twelve railroads that do poorly on one of the measures. This information would allow the FRA to set priorities for the work of their inspectorate to determine whether it is necessary for the FRA to set in motion the remediation phase of the delinquency system.

INFORMATION ON SMALL RAILROADS

Statistical analysis of accident rates or employee injury rates would only be possible for the largest forty or so railroads. Statistical analysis would be impossible for very small Class II and all of the Class III railroads. For these railroads other sources of information might have to be collected. to allow the FRA to make judgements on which railroads deserve closer inspection. A parallel can be drawn here to the problems faced by the FHWA's Office of Motor Carriers who have to control safety in an industry dominated by small carriers. Clearly, the FRA can review individual accident reports from these smaller railroads to see if the accidents had causal factors that might suggest lax safety precautions. It is also likely that traditional random inspections of track and equipment may be necessary for smaller railroads so as to provide information on the safety practices of these railroads. An alternative strategy is to conduct an annual audit of each small railroad. This is not an unrealistic suggestion given that there are only three hundred different corporate entities involved. During the annual inspection, management could be questioned on safety issues that have arisen during the year, the responses by management, and information could be obtained on financial conditions which might suggest whether myopic behavior is expect. If an accreditation system is adopted as part of the educational role for new railroads, it may be convenient to have a formal system of annual re-accreditation.

ALL CHANGE AT THE FRA

There needs to be fundamental change at the FRA. The old way of doing business with the employment of ex-railroad inspectors to inspect track and equipment is wasteful and ineffective. As summarized in table 20.7, the "new" FRA will be somewhat schizophrenic in that it must be both a teacher and a police officer. In its role as an educator it would work with other interested parties to ensure that managers of inexperienced railroads are fully aware of the choices they have to make to provide a safe service. There would be a fundamental switch to formalized education and away from inspections.

In preventing and punishing myopic railroads, there would be a fundamental change from employing inspectors to employing risk analysts. It only makes sense that the FRA uses statistical analysis of the safety performance of Class I and most Class II railroads to direct the activities of those in its workforce who are involved in enforcement and remediation duties. In this new world, written regulations governing the design of track and equipment and operating practices would take a

Table 20.7: Features of an Improved Safety Regulation System

	Educational System	Delinquency System
Objective	Prevent myopia by inexperienced railroads	Prevent myopia by unscrupulous railroads
Target railroads	New, usually small, railroads	Incumbent small and large railroads
Monitoring strategy	Educational seminars and visits.	Information system to identify delinquent railroads.
Written specification regulations		Used only to confirm delinquency, and as a threat to ensure remediation.
Enforcement	Issuing of Certificate of Fitness	Fines, rescinding of Certificate of Fitness, informing shippers

"back seat" unless they need to be used to support any legal penalties or sanctions to support the enforcement and remediation process.

These comments should not be taken **as** a justification for a larger FRA. It is not unrealistic to expect that by working in a smarter way the **FRA's staffing** may actually fall.

21 THE WAY FORWARD

RECOMMENDATIONS ON HIGHWAY GRADE CROSSINGS

Grade crossing collisions cause almost half of all railroad fatalities. While there have been great improvements in safety at grade crossings subsequent to a government funding initiative in 1974, there are still considerable problems.

The first is that some highway users do not exercise enough care. At crossings with flashing lights or gates, so called active warning devices, more than eighty percent of collisions are caused by the highway user ignoring the lights and/or driving around the gates. At crossings with passive warning devices such as crossbucks signs many drivers do not properly look and listen for a train. Because the conduct of highway users at crossings with passive warning signs is not explicitly defined in the law, there is some suggestion that courts hold drivers to a lower level of due care than they should.

The root of this problem is that some road users do not fully appreciate the dangers of grade crossings: trains approach a crossing much faster than might be assumed, and cannot stop quickly. The government and the railroads should be commended for their "Operation Lifesaver" campaign that attempts to educate the public of the dangers. There is a growing trend to specify conduct at crossings with passive warning devices by replacing crossbucks signs by stop signs. This is certainly not a panacea. While there may be advantages in encouraging drivers to take care, there are considerable problems including the fact that slow-moving vehicles are more likely to be hit by a train than a vehicle moving quickly across a crossing. There is an increased chance of rear-end collisions between highway vehicles at the stop sign, and the possibility that stopping for nonexistent trains may diminish the regard that drivers have for stop signs. I think that empirical research is necessary before one should support installing more stop signs.

The second problem is that there are a large number of crossings that deserve upgrading from passive to active warning devices. My estimation is that there are at least 8,500, and maybe as many as 20,000, crossings deserving upgrades. At the current rate of progress, a realistic prediction of when all deserving crossings will be upgraded is somewhere between the years 2013 and 2036. One beneficial initiative to speed up deployment of warning devices has been a program to consolidate together little-used crossings into one crossing provided with active warning devices. The consequent delays to road traffic from closing some crossings is minimal. In many locations the large number of adjacent crossings is a legacy of the era of the horse and buggy when nearly every intersecting highway was provided with a crossing.

A proactive systematic program to upgrade crossings has been hampered by the legal system which places the duty to prove safe crossings on the railroad, even though funding of and decisions on upgrades are largely in the hands of state highway authorities. The current legal system encourages railroads to respond to random collisions by pressing for installation of active warning devices at little-used crossings so as to avoid liability in the event that another collision occurs in the coming decades. Because the railroad and not the highway authority is the defendant in suits brought by highway users, evidence that the crossing did not “deserve” upgraded warning devices is not always admissible as a defense.

A 1993 Supreme Court ruling promises to change the system. Some courts have held that the involvement of federal money means that federal standards for when to install active warning devices preempt state common laws that hold railroads liable for this decision. In 1995 the federal government proposed to clarify this preemption by placing the decision to install warning devices entirely in the hands of highway authorities, who would use Federal Highway Administration rules in deciding which crossings to upgrade. The role of railroads would be reduced to just providing information on the level of train traffic, and supplying technical expertise.

Unfortunately, there is a downside in that most States have sovereign immunity against claims for damages from injured highway users. Even if they decide to waive sovereign immunity, there are often limits on the dollar amounts of claims. There are many crossings that deserve upgrades that will still not be treated in the foreseeable future because of budget limitations. Highway users killed or injured at these crossings will either be unable to seek damages or have the amount of damages severely limited under the proposed rules. Critics of the proposal correctly observed that the principal effect of the 1995 proposal would have been to limit corporate liability at the expense of individual road users.

The proposal was quiet dropped in 1997. Railroad lawyers suspect that it would only be resurrected when the mood of the country again turns toward tort reform and limitations on corporate liability.

I am supportive of the concept that the highway authority and not the railroad should be the legally responsible party. The highway authority is clearly in the best position to judge the most appropriate type of warning device as only it is privy to forecasts of road traffic and land-use changes. However, this authority must be tempered with financial responsibility for the conduct of its crossing improvement program. A waiver of sovereign immunity must be incorporated into any resurrected proposal.

RECOMMENDATIONS ON TRESPASSER FATALITIES

Trespassing fatalities have been increasing in recent years, at a time when safety at grade crossings has been improving considerable. Consequently, preliminary data for 1997 suggest that trespasser fatalities will become the largest category of railroad fatalities. It is common to think that most trespasser fatalities are children and people taking a shortcut by crossing the railroad. However, these fatalities represent less than a fifth of victims. The typical trespasser is a single adult male who is under the influence of considerable amounts of alcohol. While many are poorly educated, very few are homeless people. Most live reasonably close to the point of trespass. The railroad right of way **has** become a popular place to socialize, drink and rest. In general one must conclude that most trespassing victims take considerably less care than they should. This is reflected in the courts where trespassers or their relatives are usually not successful in any damage claims against railroads.

In contrast to the essentially rural grade-crossing problem, trespassing is primarily an urban phenomenon. This raises the question of whether the railroad should fence most or all of its urban right of way. Unlike some other countries, the railroads in North America are primarily unfenced. Calculations suggest that fencing the urban rights of way would cost about $3 billion or about $3 million per life saved. This puts fencing on the borderline of desirability based on standard values of life used in the transportation industry. However, the amount required to fence the urban right of way could be used to provide active warning devices at the 20,000 public highway grade crossings that deserve them, and still leave enough money over to provide active warning devices at the 15,000 busiest private crossings. Money spent in this way would save up to twice as many lives than if it was spent on fencing.

The above calculation was based on assumptions that are very favorable to fencing. There is considerable uncertainty about the effectiveness of fencing to reduce trespasser fatalities. The annual North-American rate of trespasser fatalities at two per million population is the same as it is in Britain where the railway is generally fenced. Closer to home, the rate of trespasser fatalities per train mile for Amtrak who run many of their trains over a fenced right of way in the North-East Corridor is ***higher*** and not lower than that on neighboring freight railroads with few fences. The general conclusion is that a general requirement to fence the urban right of way would come a long way down the priority list for cost-effectively improving safety on the railroad, and may even be a futile waste of money.

RECOMMENDATIONS ON OCCUPATIONAL INJURIES

Economic theory, dating back to Adam Smith, indicates that if workers are knowledgeable about job risks, market mechanisms will compensate workers for working in industries that are particularly risky. Workers with a greater tolerance of physical risk will tend to gravitate towards riskier occupations. A market failure will only exist if wages are insufficient to compensate for the risks. Railroad workers are among the highest paid workers in the nation whereas injury and fatality rates are low in comparison to peer industries that involve heavy, moving machinery and work outdoors. Construction, maritime, trucking and warehousing jobs have far higher casualty rates.

There are two reasons why there does not appear to be a market failure for employee safety. The first is that railroad risks are primarily physical injuries about which workers should be well informed. The second is that the high rate of unionization in the railroad industry should provide for higher-than-average levels of safety as unions are typically thought of as representing the inframarginal worker who will be less tolerant of risk than the marginal worker who determines safety in a competitive market.

While the higher wages paid by railroads benefit all workers, the costs fall on the minority of workers who suffer injuries. In the past ninety years, employers have been required to provide insurance schemes whereby injured workers are provided with compensation. The railroad industry has a different form of compensation system than that applicable to the competing trucking industry, and indeed to all other sectors of American industry. The ***Federal Employers' Liability Act*** (FELA) applicable to the railroads gives a higher level of benefits to injured workers than does the system of workers' compensation applicable to other industries, primarily because workers' compensation does not permit injured workers to claim compensation for non-monetary losses. However, awards to injured railroad workers can be reduced or eliminated if the worker was negligent, whereas awards are guaranteed under workers' compensation. Because of its judicial rather than administrative nature, FELA involves higher transactions costs than does workers compensation.

My analysis indicates that FELA is more likely to ensure that both employees and railroads take care to avoid workplace accidents. If the costs to the railroad of taking care to prevent occupational injuries are more than $2,280 per employee per year, there is the possibility that railroads may take ***less*** care if FELA was replaced by workers compensation. If this happened society will be worse off. The incentives to employees to take care are similar under both systems. While negligent employees will receive compensation under workers' compensation, the non-monetary losses which they have to bear themselves act as an incentive for taking care.

However, there is a way in which the adversarial nature of FELA increases workplace risks. Injured employees correctly respond to FELA by not wanting to reveal details of the nature of their cases to railroad managers prior to legal proceedings. Employees also have incentives to claim that the injury resulted from a violation of federal safety laws as this removes the railroad's defense of comparative negligence. This clearly works against informal sharing of information between employees and management on ways to learn from experience in mitigating injuries. Under workers' compensation the employee is guaranteed compensation, and will therefore be able to honestly admit to the circumstances of the injury and ways in which it might be avoided in the future.

There seems to be little prospect of any reform in that both management and labor are firmly entrenched. Management tends to believe that a switch to workers' compensation will save the industry considerable money. I regard that argument as spurious. FELA benefits are highly valued by railroad workers, and railroads should expect that substitution of workers' compensation for FELA will be at the expense of wages or other concessions valued by labor. However, management does have valid concerns about ***aspects*** of the ***Railroad Retirement Act*** which gives longer-serving workers no incentives to rehabilitate themselves following an injury and return to work. Much of the financial concern about the cost of injury compensation could be dealt with by changes to the ***Railroad Retirement Act*** rather than the replacement of FELA.

RECOMMENDATIONS ON OPERATIONAL SAFETY

Operational accidents, which are primarily collisions and derailments, result in about twenty-two deaths, 450 injuries and about $250 million in property damage each year. Seventy percent of the collisions and sixty percent of the derailments occur in yards and sidings during switching operations. Half of all derailments are caused by the state of the track, while eighty percent of collisions are caused by incorrect or inappropriate operating practices.

Operational safety is only one of the attributes of service that railroads offer to their customers. Other attributes include price, speed, and reliability. Relatively elementary economic models suggest that there will be a socially-optimal level of each of these attributes. This benchmark level arises because safety, and other attributes, while valued by customers, are also costly to provide. The socially optimal level of safety may not be at the point where all accidents are eliminated. It may not be cost efficient to mitigate all accident risk.

Therefore the fact that we observe over 2,000 collisions and derailments a year is not necessary an indication that there is a “safety problem” on the railroads. There is only a problem if this level of accidents is different from the socially optimal levels. The theoretical causes for such a market failure are fivefold. There will be a market failure if:
(1) railroads do not price in a competitive fashion;
(2) customers cannot accurately perceive the level of safety on offer;
(3) customers do not act rationally;
(4) railroads do not compensate bystanders for damage; and
(5) railroads are myopic in trading off the cost of preventing accidents in the present against accident costs in the future.

Let us review these five possible market failures. There is evidence that railroads do have the necessity and the ability to price above marginal cost. The ***necessity*** comes from the fact that railroads are characterized by large fixed costs of track and relatively low marginal cost of operating individual trains. This ***natural monopoly*** characteristic requires pricing above marginal cost so as to recover costs. ***The ability*** to price above cost results from the high market share they have for certain bulky commodities such as coal, ores and grain. It cannot be denied that certain railroads have become increasingly profitable in recent years. However, economic theory cannot unambiguously conclude that market power leads to lower provision of safety. Even if it did, the safety distortions might be regarded as rather minor compared with the welfare losses associated with **restriction** of output and higher prices.

For many passenger modes of transportation the major justification **for requiring** safety regulation is that the customer is not a knowledgeable purchaser. If customers cannot determine the safety of the carrier they select, they will be unable to signal their desires for safety. In the railroad industry most customers are **well-**informed. This is because they are repeat customers. Commutation passengers and shipping managers are almost daily users of the railroad system. They are able to observe the level of safety on offer. Shipping managers are continually settling claims for minor loss and damage and are well aware of the safety risks. A legacy of the many years of economic regulation is that extensive information is collected on safety, loss, and damage. ***The* AAR's *Freight Loss and Damage Report*** provides a wealth of information on the amount of damage and loss sub-divided by cause, railroad and commodity. Unfortunately this report does not circulate widely outside of a select few in the railroad industry. Wider circulation of this information would certainly reduce calls for safety regulation based on the premise that the customer is not aware of the quality of the service that is being purchased.

Socially-optimal behavior will only occur if fully-informed customers make rational choices consistent with their desires and economic incentives. In general, we can expect freight shippers to make calm and rational decisions based on the prices and safety records of different railroads and available modes of transportation. The situation with regard to passengers is less clear. Psychologists have found evidence that people might ignore safety information in their **decision-**making so as to avoid thinking about very unpleasant consequences. Whether this is a "market failure" is a matter of semantics, as the failure is within the customer and not in the trade between customers and railroads. It is possible that intervention in the market may be necessary to protect customers from themselves rather than from avaricious railroads.

A traditional cause of market failure in economics is if there are uncompensated externalities on other parties. Bystanders, such as those adjacent to the railroad, can bring suit under the laws of negligence for any losses caused If the damage is caused by a release of ultra-hazardous materials the railroad is strictly liable to pay compensation. My investigations suggest that in the vast majority of cases railroads bear the entire cost of damage caused.

However, socially-optimal exposure of third parties to risk only results if shippers are charged prices that incorporate the externality costs that a release of their product may cause. That is to say that shippers of extremely hazardous materials should pay a high price for shipment so as to allow for compensation to bystanders who are affected by a release caused by a collision or derailment. Shippers of commodities which do not cause extensive externalities should be charged lower prices. Unfortunately the railroads have done a very poor job in identifying the costs associated with individual commodities.

In many cases a standard surcharge is collect on all freight movement to cover liability costs to bystanders. As a result too much extremely hazardous materials are shipped, and too little low- or non-hazardous are shipped. Shippers of extremely-hazardous materials are therefore not given the correct incentives to reevaluate where to locate their manufacturing plants or whether to develop safer alternative products. Recent research work has identified that the amount of externalities varies considerably between commodities. Some commodities cause over one hundred and fifty times as much damage per unit shipped than other commodities. While some railroads have made some moves to incorporate these findings into their pricing, there is still a long way to go. A desirable response by the railroads to the public's concern about the transportation of hazardous materials is to ensure that pricing of railroad service fully incorporates the cost of externalities appropriate to that particular commodity.

The market failure that is most threatening and most likely in the railroad industry is that of myopia. The costs of preventing railroad accidents, such as capital expenditures and training, occur in the present whereas the costs of accidents occur at some undefined point in the future. A myopic railroad can save money on prevention in the present while either not appreciating or not caring about the consequent rise in accident costs in the future. Two types of railroads may be susceptible to such myopia. The first are newly-formed railroads who make myopic decisions due to inexperience rather than unscrupulous intent. They simply do not understand that saving on training costs now will result in higher accidents in the future. The proliferation of short-line railroads ***since*** the ***Staggers Act*** of 1980 has given some prominence to this concern. Albeit that there is little evidence that these small railroads pose an unreasonable safety threat. While these railroads do have a higher rate of collisions and derailments than larger railroads, they do not have higher fatality rates. Low speeds of operation mitigate the consequences of many accidents.

The second type of railroad susceptible to myopic behavior are those who intend to "cheat" on their customers. These railroads hope to save money in the short term by reducing expenditures on accident prevention, yet hope that their customers do not notice and react by taking their business elsewhere or demanding lower prices. There is ample evidence that this behavior has occurred in the railroad industry. Indeed the reason that extensive safety regulation was introduced in the 1970s was due to myopic behavior by certain **financially-distressed** railroads in the 1960s. These railroads indulged in a particularly insidious form of cheating in that they reduced their expenditures on track maintenance. It takes some time for a previously well-maintained right of way to deteriorate, and it was therefore some years before shippers could detect that safety was declining.

The market failure caused by myopia does not necessarily imply that safety regulations are necessary. For example, a concern about myopia by inexperienced railroads might suggest that there is a wider role for the insurance industry. Insurance assessors need to make a determination of the precautions taken by a new railroad and charge an appropriate premium to reflect the probability that accident claims will result in the future. Railroad management would be able to trade off the size of the insurance premium against the costs of preventive effort in determining the appropriate level of safety to provide. While there is no requirement for small railroads to hold insurance, most elect to do so.

Unfortunately premium schedules are relatively coarse, and insurance companies do not routinely tailor the premium to the specific preventive efforts made by individual railroads.

A concern about myopia by unscrupulous railroads could be mitigated if customers could readily detect the cheating. Customers would immediately express their concern to railroad management and demand a lower price because they are receiving a lower quality of service. There is extensive data already available on railroad accidents. Unfortunately this information is not widely understood or disseminated. The government in the form of the FRA and the NTSB as well as the industry through the AAR or ASLRRA would be well advised to make current information more widely available to railroad customers in readily understood formats. Recent advances in electronic dissemination of information have substantially reduced the cost of doing so.

Of course, provision of accident data is not a panacea for removing incentives for cheating. Reductions in maintenance can occur long before they are reflected in accident rates. A purely informational response to a market failure due to myopia would therefore need to provide information on safety inputs such as maintenance activities, training and the age and condition of capital equipment. These are much more difficult metrics to measure and to convey to customers than are accident data. For smaller railroads, information on accidents in a given year is unlikely to provide useful information on whether the safety precautions undertaken by that railroad are deteriorating. Accidents are rare events and it my be difficult to determine from year to year whether the occurrence of an accident is due to myopic behavior or simply due to statistical chance.

While one should support the provision of greater information and encourage insurance companies to be more discriminating in setting premiums, there is probably some role for direct regulation by the government to reduce the chance of myopia. The big question is whether the traditional forms of regulation practiced by the FRA are appropriate for this role, and whether new and improved regulatory strategies could lead to more effective and more cost-efficient ways to prevent myopia.

Some safety regulations date back a long time. These older regulations tend to be supportive of informational and legal response to market failures. The liability of railroads to employees, shippers, and to bystanders affected by munitions explosions date back to the earliest part of the twentieth century. Railroads have had a requirement to report accidents to the government, and to submit to independent investigation of major accidents, since the same period.

The regulations that have drawn the most criticism are those that date from relatively recent times. This is not to say that railroads have not had their own self-enforced regulations for many years. The very necessity for railroads to exchange cars and locomotives between themselves to provide customers with through service has required standardization. Railroads devised interchange standards for equipment as far back as 1867 and have a recommended code of operating rules dating from 1887. Prior to 1970 these rules were self-administered and not written into federal regulations. ***The Federal Railroad Safety Act*** of 1970 provided the newly-formed

FRA with the powers to "promote safety in all areas of railroad operations." Subsequently regulations were promulgated that wrote freight-car interchange standards into law, devised new standards for railroad track, specified locomotive standards, provided for certification of locomotive engineers and codified certain operating rules into law. Enforcement of these regulations is provided for by the employment of four hundred federal and state inspectors who conduct semi-random inspections of railroads and bring citations and fines for violations found. The FRA also conducts "task force or special assessments" where teams of inspectors undertake comprehensive evaluations of particular railroads. The FRA has the power to issue notifications to require immediate rectification of defects, and in the extreme can forbid operation by a railroad.

The regulations of the 1970s have drawn criticism not only from railroads but also from independent government agencies such as the GAO and the late OTA. The criticisms focus on both how the regulations are written and how they are enforced. The regulations concerning track standards and brakes in particular have been criticized because of a lack of cost-benefit analysis in setting of the standards. It is possible that organized labor has been able to coerce Congress so as to write rules that preserve existing working rules. There is an additional concern that even when appropriate standards are written into law, the rulemaking process necessary to update these standards in the face of technical change or modem requirements is so lengthy and stifling that regulation can impede progress. The main cause of this problem is the penchant of Congress and the FRA to express standards in terms of the design of equipment rather than the performance of it. One would imagine that the FRA is really only interested in how quickly a train can stop or whether there is excessive lateral deviation in track, and not in the specific design of the braking equipment or the number of spikes per section of track.

The enforcement of the regulations has been subject to much criticism. There is considerable feeling, not only in the railroad industry, that semi-random inspections resulting in violation notices and fines are ineffective in improving safety. There is evidence that this is true in the trucking industry, and even OSHA has recognized that there must be a better way of obtaining a safe workplace. Reports by the GAO suggest that the FRA does not have adequate models to determine which railroads pose the greatest safety threat and therefore cannot reasonably set priorities for targeted or special assessments of individual railroads. There is also evidence that the tactics of FRA inspectors have antagonized rather than enrolled railroad managements in the cause of safety. Resolution of violations and the payment of fines by large railroads does not normally involve senior officers of the railroads, and there is little evidence that the fines influence corporate policy.

Perhaps the most damning criticism of the 1970s regulations is lack of any strong empirical evidence that these regulations have led to improvements in safety. It is certainly true that railroad safety was declining from the 1960s through the late-1970s, and has improved substantially since.' However, other changes have occurred that may explain the decline in accident rates. The railroad industry was deregulated in 1980 and the improved financial viability of individual railroads has allowed increased expenditures on track and equipment. The railroad industry has also changed away from individual-car service towards block trains which reduce the amount of switching and hence the potential for collisions and derailments.

So how can we improve on this rather dismal performance by the legislators who write railroad regulations, and the FRA who enforce them? The answer to this question comes from reflecting on the market failures that the government is hoping to prevent. My analysis suggests that the major role for the FRA is to prevent myopia by inexperienced railroads or unscrupulous railroads. Dealing with these two types of myopic firms calls for two different approaches. An educational system is needed to prevent myopia by inexperienced railroads, while a delinquency system is need to detect and punish unscrupulous myopic railroads who are trying to cheat their customers. The FRA needs to be both a teacher and a police officer.

To a certain extent the FRA already serves as a teacher. Seminars are held jointly with ASLRRA for managers of newly-formed railroads. Press reports suggest that people attending such sessions have found them to be very useful. The objective, of course, is to ensure that managers are made fully aware of the safety consequences of the decisions they are making on training, maintenance, and capital purchases. The FRA should expand its role in cooperation with ASLRRA, the AAR and the insurance companies. All of these organizations have interest in ensuring that new railroads do not pose unreasonable safety risks and also have considerable expertise to pass on. The question arises whether new railroads should be accredited before they are allowed to operate. This accreditation may be based on attendance at these seminars or on other factors.

There are two possible models that the FRA might look to. The first is the system of safety audits undertaken by the FHWA of trucking companies. A questionnaire is completed by a federal inspector which is used to rate the firm on the basis of the safety management practices that it has put in place. Perhaps a better educational tool is the "Railway Safety Cases" which had to be completed by private operators who wished to take over the services formerly provided by the state-owned railways in Great Britain. In addition to requiring details of the safety management systems put in place, operators had to complete a risk-assessment exercise in which they had to identify the major safety risks they faced, appraise the probability and severity of these risks, rate the risks and provide plans for ameliorating those risks that were too high. While data on risk probability and severity may be limited and rating of risks is judgmental, the important role of the risk assessment is to require railroad managers to think deeply about the risk faced and the ways in which the railroad can reduce the risks. It is unlikely that a new railroad that has to undertake a risk-assessment exercise will be myopic due to inexperience.

A delinquency system is not much different in intent from the current activities of the FRA. The objective is to identify those railroads providing sub-standard service or those whose safety record is precipitously declining. The FRA's enforcement role is aided considerably if customers are made aware of declines in the safety offered by an individual railroad. Customers will then pressure railroad managers to restore the previous level of quality or demand a discounted price. The FRA should be encouraged to make the findings of its monitoring and enforcement efforts well known.

These comments should not be taken as an endorsement of the **FRA's** current methods of monitoring safety performance. Far from it. Semi-random inspections based on finding violations with federal requirements that may or may not be related to safety performance is a bankrupt method of safety control. The system that I am proposing is a four stage process. The first stage requires the FRA to adopt the role of risk analyst. The FRA would analyze data on safety **performance** for individual railroads to determine which railroads might be delinquent. The second stage involves inspections and evaluations of railroads that the first stage has flagged as potentially delinquent so as to confirm or disprove the **FRA's** suspicions.

The third stage requires a delinquent railroad to prepare a remediation plan to correct its delinquent behavior. The FRA would also wish to involve the customers of the railroad at this stage so that they can also put pressure on the railroad. The fourth and final stage requires the FRA to monitor whether the railroad is making a good-faith effort to implement its remediation plan. Failure at this stage would trigger traditional methods of inspections, citations and fines. Of course, the FRA retains the powers to issue Special Notices or Emergency Orders to limit operations of specific equipment or stretches of track if it detects extremely dangerous conditions.

Such a system is in use in the trucking industry. The FHWA uses information on the accident rates of carriers, and other information it has, to set priorities for the work of its inspector-ate. OSHA conducted an experiment in the state of Maine in 1993 whereby the largest firms where exempted from the traditional OSHA inspections if they made self-assessments of workplace risks, prepared a plan to ameliorate the risks, and made good-faith efforts to implement their plans.

The hardest part of the proposed system is to design an information system that can be used by the FRA to provide an early warning of railroads who may be cheating. An obvious input to such a system is the information that is currently collected on accidents and workplace injuries. While accidents are random events which leads to some natural variation in the number of accidents a firm will have from year-to-year, there are well-understood statistical rules that explain the nature of this variation. Providing the measures of safety that are used occur at least about ten times a year for individual railroads, it is realistic to expect that the FRA can define statistical rules that effectively identify those railroads whose accident performance is deteriorating or is worse than peer railroads. Candidates for such measures of accident performance are the number of collisions and derailments, and the number of employee fatalities and injuries. The very simple analyses conducted in chapter 20 provide the basis for identifying those railroads whose safety performance is wanting.

However, this is essentially an ***ex-post*** identification of myopic railroads. It is clearly preferable if the FRA could identify railroads who are acting myopically before their reductions in preventive efforts are reflected in increased accidents. The **FRA** might develop a system of warning flags for railroads whose circumstances might suggest myopic behavior, such as financial distress, declines in revenue, financial restructuring, stock offerings or being a takeover target. The FRA might also wish to develop information on safety inputs to alert them to railroads that do not appear to be spending sufficient amounts on track maintenance or who are allowing the average age of their fleets to increase, or who have inordinately high staff turnover. Such warning flags could trigger inspections or a special assessment of the railroad.

Such a statistical risk-analysis approach to analyzing data on safety inputs and outputs is only really applicable to the largest forty or so railroads. The smallest Class II and all of the Class III railroads have accidents so infrequently that any statistical inference would be impossible. The average-sized Class III railroad injures four employees a year, has one grade-crossing accident a year, kills a trespasser once every twenty years and has a collision or derailment once every seven-and-a-half years. It would also be infeasible to collect extensive financial or safety input data on these railroads.

Does this mean that traditional random inspections of track and equipment will have to be retained for smaller railroads? That is certainly a possibility. A more productive method may be an annual audit of each small railroad. This is not an unrealistic suggestion as many small railroads are either owned by larger railroads or are subsidiaries of larger holding companies that own many short-line railroads. There are perhaps only three hundred different corporate entities among the small railroads. During an annual audit the FRA inspector would be able to question management on safety challenges encountered in the past year, the response made by management, future safety plans and possible changes in financial conditions that might suggest myopic cheating. The inspector could also randomly inspect maintenance records, employee qualification files and also track and equipment to ensure that the physical condition of the railroad squares with the report given by management.

IN CONCLUSION

The railroad industry has really only got itself to blame for the current mess it is in with regard to safety regulation. In the 1960s certain managers responded to financial distress by a disregard for safety. Accidents rates, which had been improving for many decades, started to increase. Quite appropriately the public demanded that Congress take action. ***The Federal Railroad Safety Act*** of 1970 is an understandable response to the circumstances. While the industry had long-standing systems of self regulation, these had failed to exercise discipline over certain railroads.

Unfortunately the new-found public interest in railroad safety was hijacked by two forces. The first was empire building by the FRA which at that time was only three-years old and looking for a mission in life. Albeit, that there is some evidence that the FRA made a preemptive strike so as avoid the railroads falling under the rulemaking powers of the newly-formed OSHA. The second was the labor unions who attempted to prevent certain long-overdue reforms of working practices by trying to write these practices into law under the guise of safety regulation.

Perhaps the biggest mistake was the enforcement strategy adopted by the FRA. The FRA hired existing inspectors from the railroads as its own inspectors. This is not to criticize the professional abilities of the people involved but merely a reflection that the enforcement stance of the FRA became to go out, inspect things and write citations. Never mind the fact that these inspections were somewhat pointless and did not encourage railroads to change their practices. If anything they did the reverse, they antagonized railroad management and did not foster a cooperative spirit of mutually trying to tackle real safety problems.

In this book I have tried to chart a way forward for the "new" FRA. An FRA that is staffed by people with the outlook of teachers and risk analysts rather than that of police officers. By doing so the FRA can target the real causes of the "railroad safety problem" and do so at reduced cost.

APPENDIX A: FEDERAL REGULATIONS

This appendix provides the reader with a sense of the federal safety regulations. The various regulations have been grouped into nine broad types: standards for locomotives and cars, track standards, operating procedures, signalling, grade crossings, employee regulations, carriage of hazardous materials, federal oversight, and accident reporting.

Railroad-safety legislation is within Title 49 of the United States ***Code of Federal Regulations,*** and occupies parts 40, 174-180, **209-245** and 840. Each of the regulations summarized starts with its part number, and also an indication of the date and the legislation by which the regulations were introduced. The following abbreviations are ***used*** for ***certain*** Acts: ***FRSA*** 1970 is the ***Federal Railroad Safety Act*** of 1970, ***HMTA*** 1975 is the ***Hazardous Materials Transportation Act*** of 1975, ***FRSAA*** 1976 is the ***Federal Railroad Safety Authorization Act*** of 1976, and ***RSZA 1988*** is the ***Rail Safety Improvement Act*** of 1988.

LOCOMOTIVE AND CAR STANDARDS

49 CFR 215 Freight Car Standards ***(FRSA*** 1970)

Defines car defects with regard to wheels, axles and boxes, body and couplers. Freight cars must be inspected for defects before a train departs and also when cars are interchanged between railroads. While cars are often owned by shippers and third parties, the requirement for compliance with the Act is with the railroad. A railroad should refuse to accept such a defective car, or just haul it to a place of repair. Three Supreme Court cases going back to 1895 indicate railroad has an absolute duty to inspect cars it receives from another railroad, and hence is liable from harms caused by a defective car (Kenworthy, 1989).

49 CFR 223 Glazing Standards (1979)

Specification of impact standards to be applied to locomotives, cabooses and passenger cars windows.

49 CFR 229 Locomotive Safety Standards (1980)

Defines defects in brake systems, couplers, suspension, wheels and tires. Sets requirements for fuel cut offs, electrical collectors, steam generators, slip/slide alarms, speed indicators, snowplows, headlights and other lights (strobes, ditch lights), and from 1995 event recorders on locomotives of trains that exceed thirty miles per hour. The regulations set design requirements for cab noise limits, and specifies reinforcement of cabs and the provision of anti-climb devices to avoid locomotives riding up over each other and crushing the train crew. The regulations specify that locomotives are visually inspected daily. Every three months brake gauges, electrical devices, jumpers, steam generators and event recorders must be inspected. Air brake filters and brake relays and valves need to be tested each year, and air brakes systems and main reservoirs every two years.

49 CFR 230 Locomotive Inspections ***(Locomotive Inspection Act*** 1911)
Applies to steam locomotives, and has not be shown in full in the federal regulations since 1980.

49 CFR 231 Safety Appliance Standards ***(Safety Appliance Acts*** 1893, 1903, 1910, 1958)
Requires the fitting, and specifies the standards, for handbrakes, running boards (on roofs), sill steps, ladders, handholds and uncoupling levers. These are shown in detail for different types of equipment: box cars, hoppers **&** high sided gondolas, low sided and drop end gondolas, flat cars, tank **cars,** cabooses, passenger cars and steam locomotives.

49 CFR 232 Power Brakes and Drawbars ***(Safety Appliance Act Amendment*** 1958)
Since 1910 continuous air brake have to be fitted throughout a train with the engineer able to operate the brakes of eighty-five percent of cars. The regulations specify the piston travel and air pressure in the systems. Air brakes must be tested at terminals, when the consist changes and every 1,000 miles. Since cabooses were removed, radio-controlled one-way "end **of** train **devices"** have been substituted allow the engineer to determine brake pressure at the end of the train. The regulations set specifications for these devices. The regulations have since 1893 required **drawbars** to be at a standard height.

TRACK STANDARDS

49 CFR 213 Track Safety Standards ***(FRSA*** 1970, 1982)
Track is divided into seven categories depending on written engineering specifications of gauge, alignment, elevation, number of cross-ties, and mismatch of railends. The maximum allowable speed **of** trains depends on the classification of the track and is shown **in** table 18.2. **In** 1982, **an exemption to** these regulations was introduced for track not used for hazardous materials or passengers with a maximum speed of ten miles per hour. There are specified design criterions for frogs and switches. Maximum speeds for curves are specified based on curvature and elevation. The regulations also specify

how frequently track should be inspected, and sets minimum experience for track inspectors

OPERATING PROCEDURES

49 CFR 217 Operating Rules (1974 revised 1994)
The larger Class I and II and passenger railroads must submit copies of their operating rules to the FRA. The smaller Class III railroads must have them available at their main offices. Records of testing and inspection of track and equipment must be kept for one year, and there must be tests of employees to ensure that they are familiar with the operating rules.

49 CFR 218 Operating Practices ***(FRSAA*** 1976)
Designates a blue signal to protect non-train crew when they go underneath or between cars. They can also be placed on switches to protect people working on track. Speed limits are required within yard limits. Flag protection is required of stopped or stalled trains. Tampering with safety devices is prohibited.

49 CFR 220 Radio Standards (rule making 1977)
Contains details on radio procedures, and how to make radio transmissions.

49 CFR 221 Rear-End Marking Devices ***(FRSAA*** 1976)
Requires and details marking devices to signify the end of a train, and provides a list of approved manufacturers.

SIGNALLING

49 CFR 236 Installation and Repair of Signals ***(Signal Inspection Act*** 1920, 1937, 1968)
Block signalling, whereby trains running in the same direction are kept a certain distance apart, is required on lines with passenger trains moving at more than sixty miles per hour or freight trains at more than fifty miles per hour. This system also prevents trains running in opposite directions from entering the same section of track. Automatic train control, whereby electrical or mechanical devices are deployed to prevent trains running past signals at danger, is required where trains operate at more than eighty miles per hour. There are requirements for track circuits which are used by signal systems to detect if a certain stretch of track is occupied by a train. The traditional semaphore signals must be inspected every six months and tested every two years. Detectors which show which way a switch is set must be inspected every three months. The regulations also sets standards for absolute block, interlocking, point locks and cab signals.

49 CFR 235 Modifications to Signal Systems ***(Signal Inspection Act*** 1920, 1937, 1984)
Provides for procedures to seek relief from provisions of Section 236.

GRADE CROSSINGS

49 CFR 234 Grade-Crossing Systems (*RSIA* 1988)
Activation of active warning devices must be twenty seconds before the arrival of the train. If barriers are fitted they cannot start descending until three seconds after lights are activated, and must be fully down five seconds before the train. There must be monthly inspection of physical condition of systems, standby power, gates, warning system, and highway signal preemption; and a yearly test of the length of warning time, and the alignment of lamps. Railroads have to file their inspection and maintenance procedures with the FRA. There is a requirement that reports have to be filed on crossing equipment failures.

EMPLOYEES

49 CFR 240 Certification of Locomotive Engineers (*RSIA* 1988)
The regulations set requirements for sight and hearing. A written test for knowledge of rules is required, and skills must be examined either on the road or on a simulator. Railroads must also consider an applicant's motor vehicle driving record in previous three years, any railroad rules violations in previous five years and whether the applicant is enrolled in a substance abuse program.

49 CFR 228 Hours of Service ***(Hours of Service Act*** 1907, amended 1969 and 1976)
Operating employees can only work twelve hours in twenty-four, must take at least ten hours rest after twelve hours of duty, and must rest for at least eight hours in a twenty-four-hour period. Duty time includes time on the train, rest at a location which is not a terminal, rest periods of less than four hours at a terminal, deadheading (or travel) to start duty, and non-train duties. Deadheading when returning from duty is counted as neither on-duty or off-duty time. The law specifies records and recordkeeping requirements. There is also detailed rules on the construction of employee sleeping quarters and work cars.

49 CFR 214 Workplace Safety (1992, and ***Occupational Safety and Health Act*** 1970)
Deals with requirements for hard hats, eye protection and foot protection. For people working on bridges, there are requirements for safety lines, safety nets and scaffolding.

49 CFR 219 Alcohol & Drugs (1989)

Employees on duty must not be under the influence of drugs or have a **Blood-**Alcohol Content of more than 0.04 of one percent. Provision is made for testing employees after an accident, as part of **pre-employment** screening, and also with cause and on a random basis.

49 CFR 40 Workplace Drug Testing (1989)

Outlines procedures for conducting drug testing.

HAZARDOUS MATERIALS TRANSPORTATION

49 CFR 179 Specifications of Tank Cars ***(Transportation of Explosives Act*** 1960, 1964)

These requirements are administered by the AAR Committee on Tank Cars.

49 CFR 178 Hazardous Materials Packaging ***(Transportation of Explosives Act*** 1960, 1964)

Specifies performance standards for packaging of hazardous materials.

49 CFR 180 Continued Qualifications & Maintenance of Packaging (1989)

49 CFR 174 Carriage of Hazardous Materials ***(Transportation of Explosives Act*** 1960, ***HMTA*** 1975)

Contains requirements that hazardous materials cars must be inspected on interchange between railroads. Shipping papers must be provided and the materials must be appropriately placarded. Regulations are given for hazardous materials that are shipped in containers and road trailers that are placed on train cars. There are detailed instructions for loading and unloading **of tank cars,** the segregation of hazardous materials within a car or train, and on the handling of explosives, corrosives and other categories of hazardous materials.

FEDERAL OVERSIGHT

49 CFR 209 Railroad Safety Enforcement Procedures ***(FRSA*** 1970, ***HMTA*** 1975, ***Transportation Safety Act*** 1974, ***RSIA*** 1988)

Contains a statement of FRA policy concerning enforcement of safety laws. The FRA can impose civil penalties. The amount of the penalty is indicated in each section of the federal regulations. ***The Safety Appliance, Boiler Inspection, Signal Inspection, Accident Report,*** and ***Hours of Service Acts*** also allow for collection of civil penalties. The ***RSZA*** 1988 increased the amount of the fines. A 1983 amendment made railroads strictly liable for any penalties, irrespective of whether they were aware of the violation: “It shall be unlawful for any railroad to fail to comply with any rule, regulation, standard or order." The only criminal felonies under ***FRSA*** 1970 are for failures to keep records.

49 CFR 212 State Safety Participation Regulations ***(FRSA*** 1970)
Allows joint programs between the federal governments and states and provides that the federal government can pay up to half of the cost of state programs. The regulations set minimum qualifications for state safety inspectors.

49 CFR 216 Special Notices & Emergency Orders ***(FRSA*** 1970, amended 1980, ***FRSAA*** 1976)
Provides the legal powers for federal inspectors to require immediate rectification of defects with freight cars, locomotives, or track. The 1980 amendment permitted very broad and sweeping powers over "conditions or practices" which need not be confined to specific "facility or piece of equipment" which had been the original 1970 wording. Another party, such as a union or an individual employee, can force the FRA to take action under an Emergency Order.

49 CFR 245 User Fees to Cover Safety Inspections ***(FRSA*** 1970)
The costs of FRA safety enforcement activities shall be collected from railroads in user fees. The fee that an individual railroad pays is determined by a formula that divides the FRA costs across the industry on the following basis: fifty-five percent allocated based on train miles operated, ten percent on the number of employee hours, and thirty-five percent on the number of miles of road. Fees were only implemented in 1992, but authority to collect the fees has currently lapsed.

ACCIDENT REPORTING AND INVESTIGATION

49 CFR 225 Accidents & Incidents ***(Accident Reports Act*** 1910)
Requires railroads to file accident reports, and codifies the classification of accidents.

49 CFR 233 Signal System Reporting ***(Signal Inspection Act*** 1920, 1937, 1984)
Requires the filing of signal failure reports and any accidents that result from them.

49 CFR 840 NTSB Investigation of Railroad Accidents ***(Transportation Safety Act*** 1974)
The investigative powers of major accidents passed from the ICC to the FRA and ultimately to the independent National Transportation Safety Board (NTSB). Railroads are required to inform the NTSB of serious accidents within two hours. NTSB is allowed to examine all physical evidence, and the NTSB inquiry takes precedence over all other investigations.

APPENDIX B: HISTORICAL DATA

Tables B1 and B2 show the number of railroad fatalities and injuries by type of person for the turn of each decade from 1890 to 1990, and for 1994, 1995 and 1996. The source of the ***data*** is the ICC/FRA ***Accident/Incident Bulletin.*** Note that the definition of injuries to employees changed in 1975 which resulted in an almost threefold increase.

Table B3 shows data on exposure to risk. The data on train miles, passenger miles and employee hours prior to 1930 are from the ICC's ***Statistics of Railways in the United States*** (employee-hours data were first collected in 1916). After 1930 the data are from the ICC/FRA's ***Accident/Incident Bulletin.*** Data on highway vehicles registered is from the FHWA's ***Highway Statistics.*** Data on population is from the Department of Commerce's ***Statistical Abstract of the United States.***

Table B 1: Annual Railroad Fatalities

Year	Trespassers	Highway Crossings	Passengers	Non-Trespassers	Employees	Total
1890	2964	500	286	128	2451	6329
1900	4175	901	249		2550	7875
1910	4735	968	324	273	3382	9682
1920	1978	1784	264	266	2576	6868
1930	2238	1943	54	272	974	5481
1940	1988	1798	87	159	580	4612
1950	1124	1568	180	137	389	3398
1960	586	1410	32	22	198	2248
1970	517	1484	8	43	172	2224
1980	457	832	4	16	108	1417
1990	543	693	3	15	43	1297
1994	529	614	5	44	34	1226
1995	494	576	0	33	43	1146
1996	471	487	12	27	42	1039

Table B2: **Annual** Railroad Injuries

Year	Trespassers	Highway Crossings	Passengers	**Non-Trespassers**	**Sub-Total**	Employees
1890	2891	1826	2425	489	7631	22396
1900	4476	1501	4128	572	10677	39463
1910	5195	2092	12451	4138	23876	95671
1920	1909	5019	7591	3332	18716	149603
1930	2848	5353	2538	1660	13558	35872
1940	2006	4551	2530	1122	11240	18350
1950	1055	4245	3350	980	10669	22585
1960	502	3343	1463	559	5807	13710
1970	509	3363	489	681	5042	16285
1980	474	3719	593	384	5170	55379
1990	560	2223	473	349	3605	20977
1994	452	1750	497	475	3174	13352
1995	466	1687	573	416	3142	11298
1996	474	1505	513	431	2923	9635

Table B3: Exposure Measures (all in millions)

Year	Train Miles	Employee Hours	Passenger Miles	Highway Vehicles	Population
1890	721	NA	12800	-	63
1900	887	NA	16000	-	76
1910	1222	NA	32300	-	92
1920	1843	5446	47400	9	106
1930	1591	3759	26800	27	123
1940	1309	2538	23800	32	132
1950	1389	2722	31800	49	152
1960	995	1670	21300	74	180
1970	839	1195	10800	108	205
1980	718	1011	11000	156	228
1990	609	554	13200	189	250
1994	655	519	14000	195	261
1995	670	510	13700	201	263
1996	671	505	13600	202	265

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SUBJECT INDEX

decisions as to the level of pain and suffering that will be compensated. The model will assume that if railroads take less care, but employees continue to take their current care, then employees will be fully compensated for all of their pain and suffering. However, if employees take less care, and the railroad takes the current level of care, courts will not award any compensation for pain and suffering.

Currently, railroads incur FELA legal and administrative costs of $710 per employee per year. This cost will increase proportionately with the probability of an accident if either party took less than their current level of care. Plaintiffs' attorneys are employed on a contingent fee basis. Therefore their costs are borne by the railroads as a percentage of gross settlements. Plaintiffs' legal costs are estimated at 18.75 percent of gross settlements. If FELA was replaced by workers' compensation, it is estimated to have a current legal and administrative cost of $330 per employee. This cost will increase proportionately with the probability of an accident if either party took less than their current level of care.

The unknown costs of taking care by the railroad and the employee are represented by the letters A and B respectively. The range of plausible values that these variables can take can be determined by looking at the last column of table 10.2. In the context of this simple model, it is reasonable to suppose that all parties are best served when the railroad and the employees do not take less care than they current do. The maximum value of A, the cost of the railroad taking care, can be found by comparing lines four and two. The value of A must be less than $10,100 per employee per year. Likewise a comparison of lines four and three indicates that the maximum value of B, the employee's annual cost of taking care, is $4,420.

The next step in the analysis is to construct payoff matrices for the railroad and employees under both workers' compensation and FELA. These are shown in table 10.3. The costs to the parties are shown as negative amounts, with the cost to the railroad shown first and the cost to the employee shown after the comma.

In the case of FELA, shown in the upper part of table 10.3, employees will receive no compensation if they take less than current care, but the railroads maintain their current level of care. However, if employees take the current level of care, but the railroads take less care, then employees will be fully compensated Given that the value of A is less than $10,100, the railroad will always take the current level of care regardless of the actions of employees. And given that B is less than $4,420, employees will always take the current of care regardless of the actions of the railroad. Therefore FELA will unambiguously discourage both parties from taking less than the current level of care.

In the case of workers' compensation, shown in the lower part of the table, employees always receive compensation from the railroad for their medical expenses and lost wages. However, they have to bear the costs of pain and suffering. Given that B is less than $4,420, employees will always take the current level of care when railroads take less care. When railroads take their current level of care, employees will also take the current level of care provided that B is less than $3,680. This seems plausible. Therefore, it is reasonable to suppose that employees will always choose to take the current level of care regardless of the actions of the railroads. The actions of the railroads in response to this choice by employees is ambiguous. The railroads will choose to take the current level of care

Table 10.3: Payoff Matrices for FELA versus Workers' Compensation

FELA		Railroad Care: **Less**	Railroad Care: **Current**
Employee Care	**Less**	**(-29750,-5940)**	**(-2160-A,-8100)**
	Current	**(-18410,-B)**	**(-4890-A,-950-B)**

Workers' Compensation		Railroad Care: **Less**	Railroad Care: **Current**
Employee Care	**Less**	**(-6680,-23000)**	**(-2140-A,-7360)**
	Current	**(-3350,-11500-B)**	**(-1070-A,-3680-B)**

if their cost of care, A, is less than $2,280 per employee per year. This is equivalent to $548 million per year for the entire industry or about two percent of total operating expenses of the Class I railroad industry (AAR, 1997). It is therefore not clear whether railroads would or would not maintain their current level of care if FELA was replaced by a workers' compensation scheme.

There are two somewhat contradictory conclusions from this analysis. The first conclusion comes from table 10.2. Society would prefer a system of workers' compensation to FELA because of the lower legal and administrative expenses. The second conclusion comes from table 10.3. FELA will guarantee that both employees and railroads do not deviate from their current level of care. If FELA was replaced by workers' compensation, it is highly likely that employees will continue to take their current level of care, yet it is possible that railroads may exercise less care. They would choose to do if the cost of care is more than $2,280 per employee per year, which is quite plausible. If the railroads did deviate from their current level of care, society would be made worse off.

INJURY COMPENSATION AND ACCIDENT INVESTIGATION

The adversarial legalistic nature of FELA can work against a safe workplace. FELA requires injured employees prove negligence by the railroad. In addition, employees must defend themselves against arguments that they were contributorily negligent. If employees can show that the injury resulted from a violation by the railroad of federal safety laws, such as the requirements for car handholds under the

There are some types of harm that cannot be legally recovered. Businesses have difficulty in recovering harm such as lost profitability. The public sector may not be **fully** compensated for emergency response. To the extent that there are such costs that are not internalized by the railroad, a market failure will result. However, the magnitude of these costs will be very small relative to the accident costs borne, directly or indirectly, by the railroad. Hence, any resulting market failure will be small.

A more serious problem is that railroads have had great difficulty in **identifying** the externality costs associated with the different types of products they carry. As a result, a uniform surcharge was often collected on all kinds of shipments to recover the costs incurred in clean up and settling claims **from** bystanders. Consequently, railroads carry ***too much*** extremely-hazardous materials, and ***too little*** low- or **non-hazardous** products. Recent work has identified that the cost of externalities varies markedly by the type of product shipped, with some products causing more than one hundred and fifty times more damage per carload than other products. Railroads are making moves to incorporate such information into their pricing, although people in the industry have suggested that full implementation is still far off.

Table 16.2 Risk Premiums for a **800-Mile** Carload Movement

Sample Product	Type of Hazard	Risk Premium
Gravel	None	$ 0.00
Asphalt	Low environmental hazard	$ 1.36
Sulfuric Acid	Medium environmental hazard	$ 5.52
Chlorine	Poison inhalation hazard	$ 8.24
Liquid Petroleum Gas	Flammable or combustible & low environmental hazard	$ 10.64
Fuel Oil	Flammable or combustible & medium environmental hazard	$ 20.88
Phosphorus	Flammable or combustible & high environmental hazard	$ 87.04
Chloroform	High environmental hazard	$226.00

Source: **Dennis (1996)**

Currently, the average risk-premium charged to all types of traffic is $1.31. If pricing reflected the externalities caused, some products such as gravel would pay no risk premium. However, flammable or combustible products which have a low environmental hazard such as liquid petroleum gas would pay $10.64. Chloroform, which poses a high environmental hazard, would pay a premium of $226. In the later case, the risk premium would add fourteen percent to the pure transportation cost.

Currently the eastern railroads have incorporated elements of the AAR study into their pricing. This should be encouraged. Otherwise the prices charged to hazardous materials shippers would be too low, and give the wrong signals when they decide where, and in what quantities, to manufacture and ship their goods.

SUMMARY

Bystanders can obtain compensation from railroads for most of the harm suffered as a result of railroad accidents through state common laws of negligence. In most cases, the standard of proof required is quite low. The mere fact that an accident occurred is usually sufficient to establish negligence. The law will therefore act in a similar fashion to strict liability, and hence removes any market failure.